THE UNIVERSITY OF ALBERTA

THE GEOLOGY AND HYDROGEOLOGY OF THE SURFICIAL DEPOSITS IN THE DEVON AREA, ALBERTA

by

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A THESIS

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled, "The Geology and Hydrogeology of the Surficial Deposits in the Devon Area, Alberta", submitted by Gordon M. Gabert, in partial fulfilment of the requirements for the degree of Master of Science.

ABSTRACT

Surficial deposits in the Devon area are underlain by interbedded shales, sandstones, and coal seams of the Upper Cretaceous Edmonton Formation. Medium to very fine sands of Unit A are the oldest sediments overlying bedrock. The sands, known geologically as the Saskatchewan gravels and sands, are up to 80 feet thick in deep valleys cut into the bedrock. Till of Unit B overlies the sands of Unit A and bedrock where the sands are absent. The till is missing in some areas and ranges from a few feet up to 30 feet thick where it is present. Glaciofluvial gravels, sand, and silt of Unit C overlie the till. These deposits are widespread and range from a few feet to 40 feet thick. Unit C is overlain by a second till deposit, Unit D. This till is missing in some places, is thin over high areas on the bedrock surface, and up to 25 feet thick over the lows on the bedrock surface. The till of Unit D is overlain by sediments of Unit E, predominantly very well-bedded glaciolacustrine sands, silts, and clays of glacial Lake Edmonton. These sediments are increasingly and progressively coarser from the base of the unit to the top. Unit E is widespread and ranges from 20 to 80 feet thick. Aeolian sands of Unit F overlie deposits of Unit E and cover about two-thirds of the area. Sand deposits of large dunes exceed 30 feet in thickness.

Four chemical types of groundwater occur in the surficial deposits and bedrock: Type 1 is a calcium-magnesium-bicarbonate water, Type 2 is a calcium-magnesium-bicarbonate-sulfate water, Type 3 is a sodium-potassium-calcium-magnesium-bicarbonate water, and Type 4 is a sodium-potassium-bicarbonate water. The four types of water are all suitable for human consumption. Aquifers in Units E and F contain Types 1, 2, and 3 water but the last type is found mainly in a narrow

zone paralleling the river. In Unit C, Type 1 and Type 4 waters are present. Type 1 is found most commonly in a narrow zone along the river and Type 4 is found north of the zone of Type 1 water. Aquifers in Unit A and the bedrock contain Type 4 water.

The dune field as a whole is a recharge area with a discharge area occupying a narrow zone paralleling the North Saskatchewan River valley. Many smaller, shallower flow systems are present with dunes as recharge areas and interdune lows as discharge areas. A recharge area interfingers with the discharge area of the dune field in a zone paralleling the river. This recharge area probably results from the downward flow of groundwater in the area adjacent to the top of the river valley wall due to the influence of the North Saskatchewan River valley. Type 4 water in Unit A and bedrock aquifers likely belongs to a long or regional flow system.

Sands of Unit A in the buried valleys are the best aquifers in the area. A test well completed in the sands in the NW 1/4, Sec. 36, Tp. 51, R. 26, could be pumped continuously for a 20-year period at 82 imperial gallons per minute without drawing the water level in the well below the top of the aquifer. The sands of this aquifer are usually found at depths of more than 100 feet. The more permeable sand aquifers in glaciofluvial sands of Unit C will yield 5 to 15 gallons per minute to wells. These aquifers are found at depths ranging from 50 to 150 feet. The poorest aquifers are found in Units E and F at depths of less than 50 feet. Wells completed in these aquifers will yield up to 5 gallons per minute but long periods of pumping will probably result in aquifer depletion. Water levels in wells completed in these aquifers fluctuated noticeably with periods of heavy rainfall and with the seasons.

ACKNOWLEDGEMENTS

Drs. A. J. Broscoe and J. Westgate supervised the investigation of the geology, guided the writer in the preparation of the thesis, and read the manuscript. Dr. J. Tóth also read the section on groundwater chemistry. The suggested improvements in the thesis were much appreciated by the writer.

The test hole drilling and aquifer testing programs were financed by the Research Council of Alberta.

Water-well drilling contractors hired for the geological and hydrogeological investigations included: Downey Water Wells, McAllister Drilling, and Forrester Water Well Drilling, Limited. Well logs for test holes EP1, EP2, EP3, and EP4 were obtained from Elk Point Drilling Company. Elk Point Drilling Company also supplied the resistivity logs reproduced in the thesis. R. J. McGinnis provided logs for test holes M1, M2, and the Schafer well. Some samples were also obtained from test holes EP1, EP2, 65-4, and M1 by the writer at the time of drilling.

The writer is indebted to the farmers and landowners in the area who kindly granted permission for drilling on their property. Excellent field assistance was provided by R. G. H. Baines, A. Beerwald, and R. Moncrieff. H. Weiss, Research Council of Alberta draftsman, drafted the majority of the figures. Technical assistance in the analysis of samples and the drafting of figures was received from D. Withers and R. A. Steinhauer. X-ray analysis of clay minerals was done by N. Andersen of the Research Council of Alberta. A. Vanden Berg of the Groundwater Division, Research Council of Alberta, carried out the digital computer analysis of the pumping test data. V. A. Carlson, also of the Groundwater Division, provided drillers' logs for test holes 65-4, E9, and E18.

Discussions with other graduate students and my colleagues at the Groundwater Division, Research Council of Alberta, contributed much to the formulation of ideas for presentation of the thesis material.

Finally, the writer would like to express his appreciation and thanks to Miss D. Cunliffe for the typing of the thesis.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF PLATES

INTRODUCTION

Location and Extent of Area

The area of study (Fig. 1) is located southwest of the city of Edmonton, Alberta, and includes Tp. 51, R. 26, W. 4 and portions of the adjacent townships. The area extends over approximately 70 square miles and is located north of the North Saskatchewan River. The investigations of the geology and hydrogeology were concentrated in Tp. 51, R. 26, W. 4. The North Saskatchewan River section mapped during the study is located in the NW 1/4, Sec. 36, Tp. 50, R. 26, W. 4, on the south side of the river.

Physiography

The area is characterized by sand dunes. Bayrock and Hughes (1962) described the dunes as follows:

> "The dunes are closely spaced in township 51, range 26, with small lakes and swamps commonly occupying the inter-dune areas. The dunes are longitudinal (linear) and parabolic (U-shaped); the parabolic dunes are concentrated near the central part of the dune area and the longitudinal dunes along the northeast boundary. Few of the dunes exceed 40 feet in height; some longitudinal dunes attain a length of over two miles."

Elevations in the map-area range from 2,325 feet above mean sea level in the northwest to 2,250 feet along the top of the North Saskatchewan River valley wall. The river bed has an elevation of less than 2,075 feet.

The North Saskatchewan River traverses the southern and eastern margins of the area. Tributaries are short and deeply incised. Drainage over the

majority of the area is internal, particularly in the dune region.

Climate

The climate of the Edmonton district is dry, subhumid, continental according to Thornthwaite's (1948) classification as calculated by the writer. Meteorological data for the city of Edmonton for the period 1881-1964 give an annual average temperature of 36.9°F, an average annual precipitation of 18.64 inches, and an average wind velocity of 8.9 miles per hour.

Population and Industry

The area is populated by farmers and by people who are employed in the nearby city of Edmonton. Part of the Leduc-Woodbend oil field is in the area and provides local employment opportunities. Groundwater development to date has been almost entirely for domestic use and stock-watering purposes.

Purpose of Study

The study initially was for the purpose of locating a buried valley evident on an early map of the bedrock topography drawn by Carlson (1967) and for determining the nature of materials filling the valley. If the materials constituted a major potential aquifer a pumping test on a well completed in the materials was planned.

Subsequent exploration by test drilling proved the existence of a major buried-valley type aquifer and the pumping test program was carried out. Supplementary information about groundwater quality and other aquifers in the area was also obtained in order to discuss the groundwater resources in more detail. Useful data related to the stratigraphy of the surficial deposits in the area were found to be very sparse and consequently a program was undertaken to establish the sequence and nature of surficial deposits and to further investigate the groundwater resources

in the area.

The culmination of this work presented in this thesis is a discussion of the groundwater resources within the framework of the surficial deposits and an evaluation of the major buried valley aquifer in the area.

Methods of Investigation

The geological and groundwater studies were predominantly subsurface investigations accomplished by the use of rotary and cable-tool drilling rigs. Water samples for chemical analysis were taken from existing water wells and from test holes drilled in the area. Samples of the surficial deposits were taken from each test hole for detailed analysis. A section of exposed surficial deposits in the North Saskatchewan River valley was also described and sampled. The section contained representative units of all the deposits encountered during test drilling. Evaluation of the major aquifer in the surficial deposits was done by means of a pumping test.

Previous Investigations

A number of published reports refer to broad aspects of the geology in the study area but only detailed reports of the geology and groundwater resources of the area are discussed here. Bayrock and Hughes (1962) mapped the surficial geology of the Edmonton district. The characteristics and origin of the deposits in the district were discussed in detail. Figure 2 is a partial reproduction of Bayrock and Hughes' map of the surficial geology in the area of the present study. Farvolden (1963a) showed the location of major valleys on the bedrock surface in the Edmonton-Red Deer map-area using subsurface and surface data. Farvolden (1963b) also described the development of the bedrock surface and described the pattern of the various valley systems on the bedrock surface of the south half of the province. The detailed

drainage pattern on the bedrock surface in the Edmonton district was shown on a bedrock topographic map with a 25-foot contour interval by Carlson (1967). Carlson also outlined areas of thick sand and/or gravel in the surficial deposits that warranted exploration as possible sources of groundwater. The bedrock topographic map in the area of study has been reproduced in figure 3. Information obtained by the writer for test holes 65-1, 65-2, 65-3, EP1, EP2, and EP3 was used in drawing the bedrock contours. Domenico (1963) studied the geology and groundwater hydrology of the Edmonton Formation in the Edmonton district.

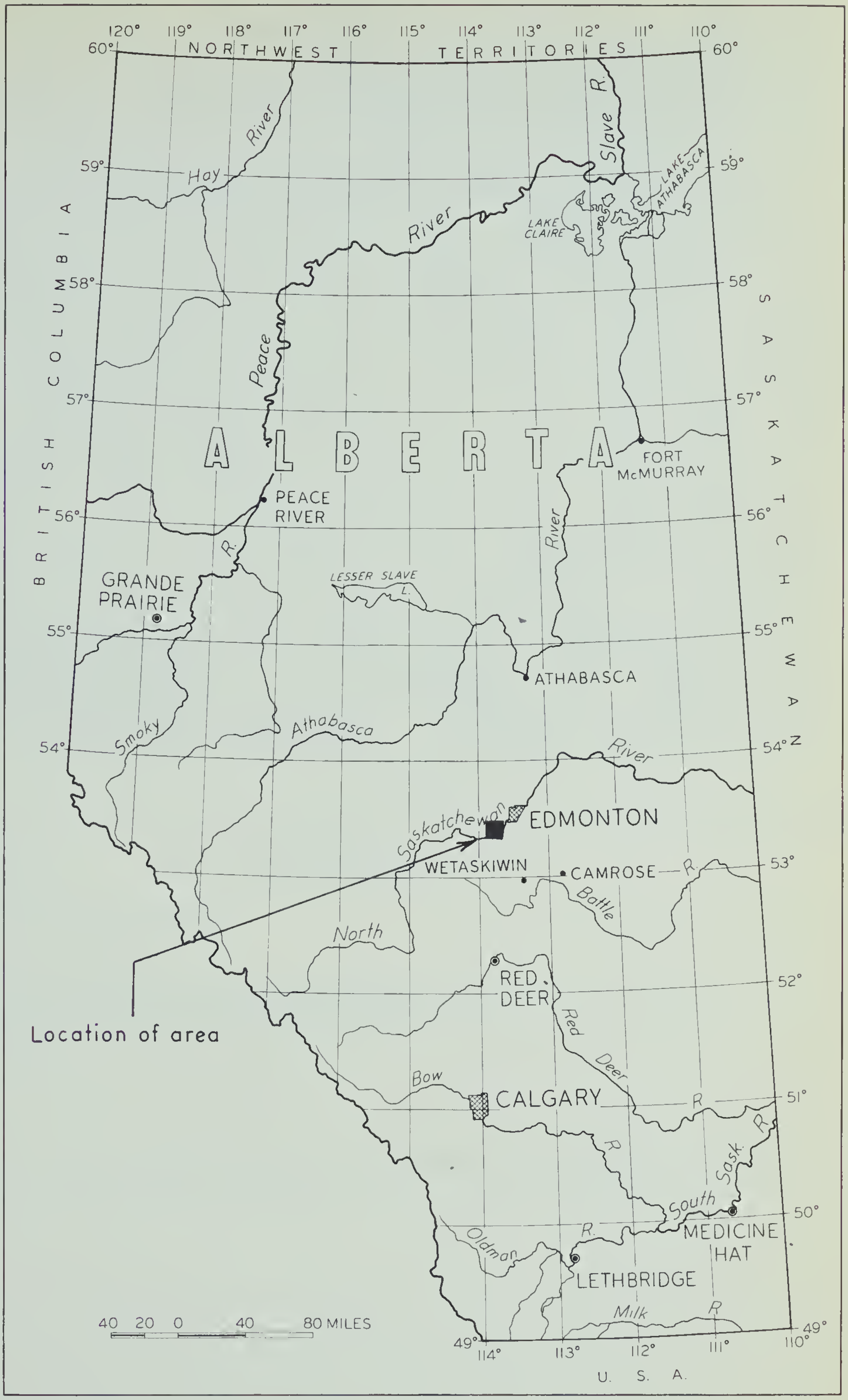
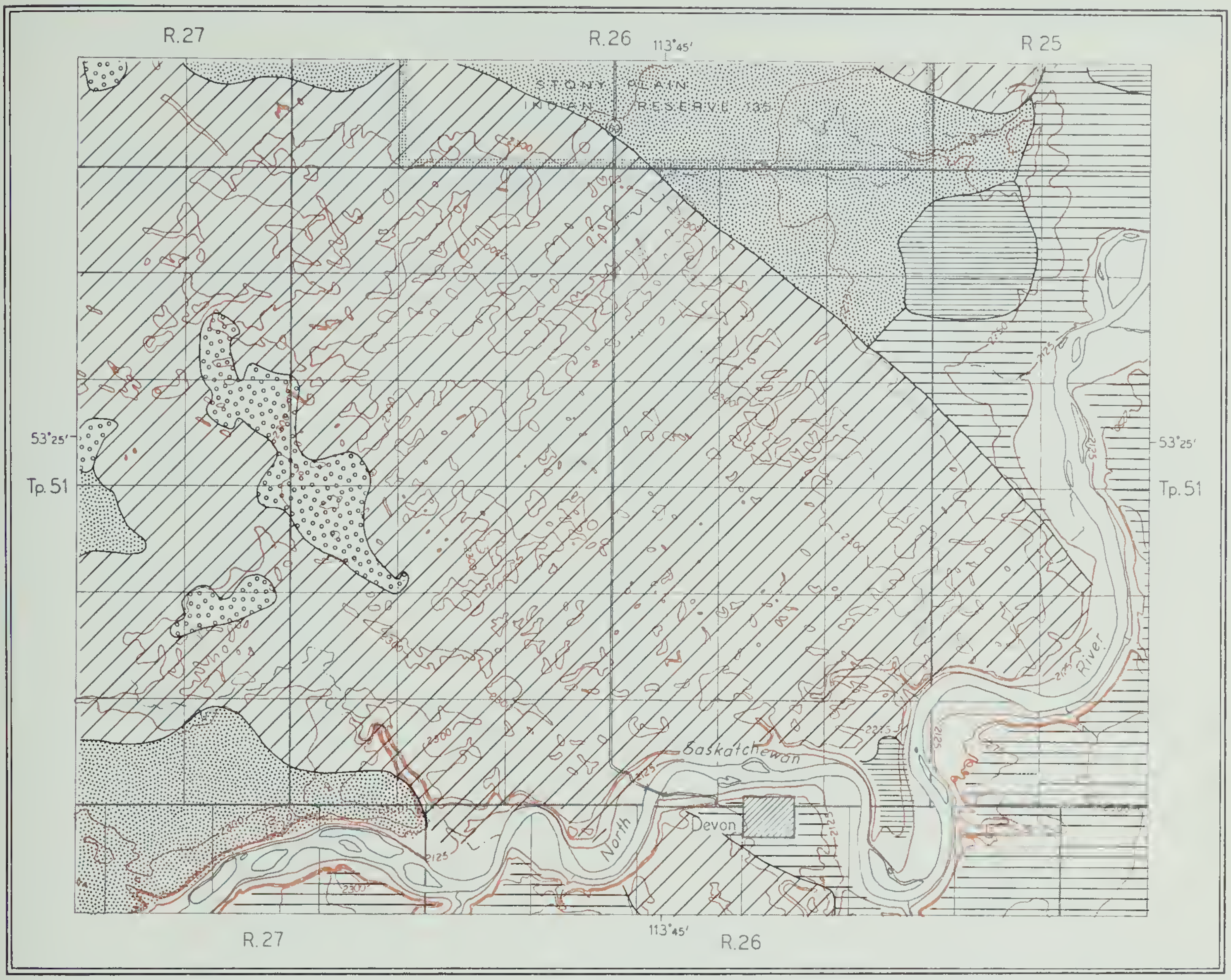


Figure 1. Index map



LEGEND

QUATERNARY PERIOD

RECENT EPOCH

Bottomland sediment: clay, sand, peat, muck and marl.

Aeolian: wind blown fine to medium grained sand.

PLEISTOCENE AND RECENT EPOCHS

Early North Saskatchewan River alluvium: mainly sand, minor pockets of coarse sand and gravel.

Lacustrine (lake) sand: mainly impure sand (sand with silt and clay); associated with final stages of Lake Edmonton and overlying Lake Edmonton sediments.

PLEISTOCENE EPOCH

Lake Edmonton sediment: silt and clay bedded and varved, minor sand.

SCALE IN MILES

1 0 1 2 3

WEST OF FOURTH MERIDIAN

Figure 2. Map of surficial geology (after Bayrock and Hughes, 1962)

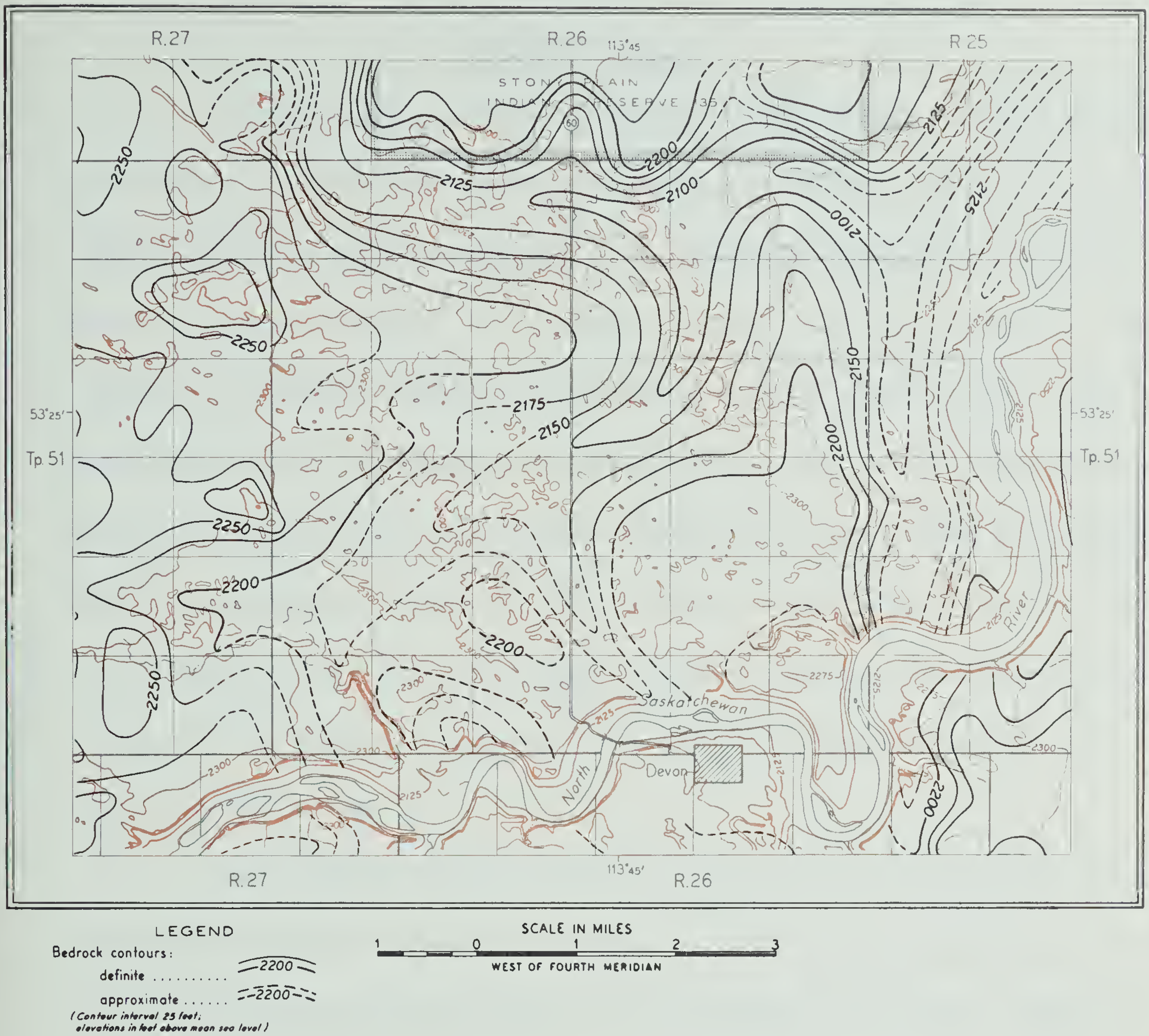


Figure 3. Map of bedrock topography (after Carlson, 1967)

GEOLOGY

Field Techniques

A cable-tool rig was used for exploration test drilling. Samples of surficial deposits were obtained by two methods during test drilling. The first method was the collection of drill cuttings during the normal drilling-bailing of cuttings cycle in cable-tool drilling. To insure that unmixed, representative samples of the deposits were obtained, casing was installed and driven frequently so that only a short interval of the test hole was uncased at any one time. An effective seal between the casing and the test-hole wall was obtained by using casing with a diameter slightly larger than that of the test hole. Casing was often driven a few feet deeper than the bottom of the test hole in sandy material and drilling was done inside the casing. Gravel and sand or material with a high moisture content were usually sampled by this method.

The second method of sampling was executed with a 5 inch O.D. drive sampler (Plate 1a) with an extraction plunger operated by a hook device which was placed on top of the plunger through a slot in the side of the sampler. Drilling was efficiently accomplished with this device as well as sampling. Bulk samples of material with low moisture contents could be obtained with the sampler. The materials which could be sampled included till, silty sand deposits, silts and clays, and bedrock deposits. Examples of core samples are illustrated in Plate 1b.

The method of sampling often depended on whether the drilling bit or drive sampler was being used for drilling.

Samples of bedrock material and the lower three parts of the surficial deposits were predominantly drill cuttings. Bulk samples of the upper three parts of

the surficial deposits were taken with the drive sampler.

The samples were described in the field at the time of drilling and a log of each test hole prepared. The color of wet, unoxidized samples was described by comparing the samples with a Munsell rock-color chart. The logs for test holes drilled during the geological investigations and other logs discussed in the thesis are found in Appendix C.

Sand filling buried valleys had a tendency to heave up the drill hole as the head of water in the hole was lowered by bailing. To prevent this the pressure head for groundwater in the aquifer was maintained by adding water to the drill hole during bailing. This procedure made it possible to sample the sand in the normal manner.

One purpose of the drilling program during the summer of 1967 was to sample the groundwater at various depth intervals below surface to determine the change in water quality with depth. To assure that the groundwater samples were representative of the depth interval sampled the minimum amount of drilling fluid (surface water) necessary to drill was used. Drilling with the drive sampler required little or no drilling fluid. Samples of water from water-bearing beds were obtained after the hole was bailed dry and the water level allowed to recover for 30 minutes. It was usually necessary to filter sediment from water samples before chemical analysis.

Test holes were located so that a north-south and an east-west cross section of the surficial deposits could be explored. The locations of test holes drilled by the writer and other test holes are shown in figure 4. Geologic cross sections, graphic logs of test holes, and resistivity logs are illustrated in figures 5, 6, and 7.

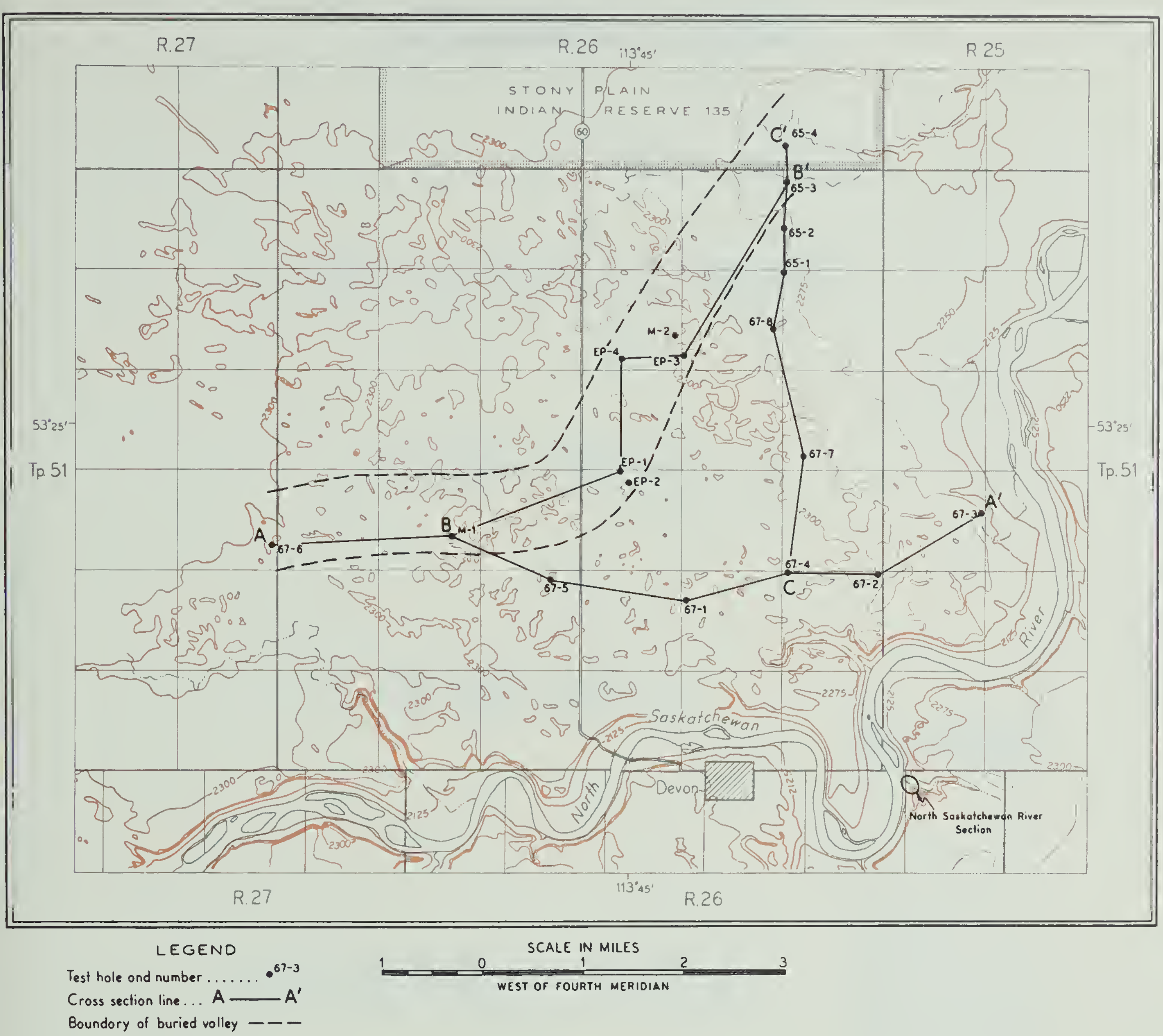


Figure 4. Locations of test holes, geologic cross sections, and buried valley

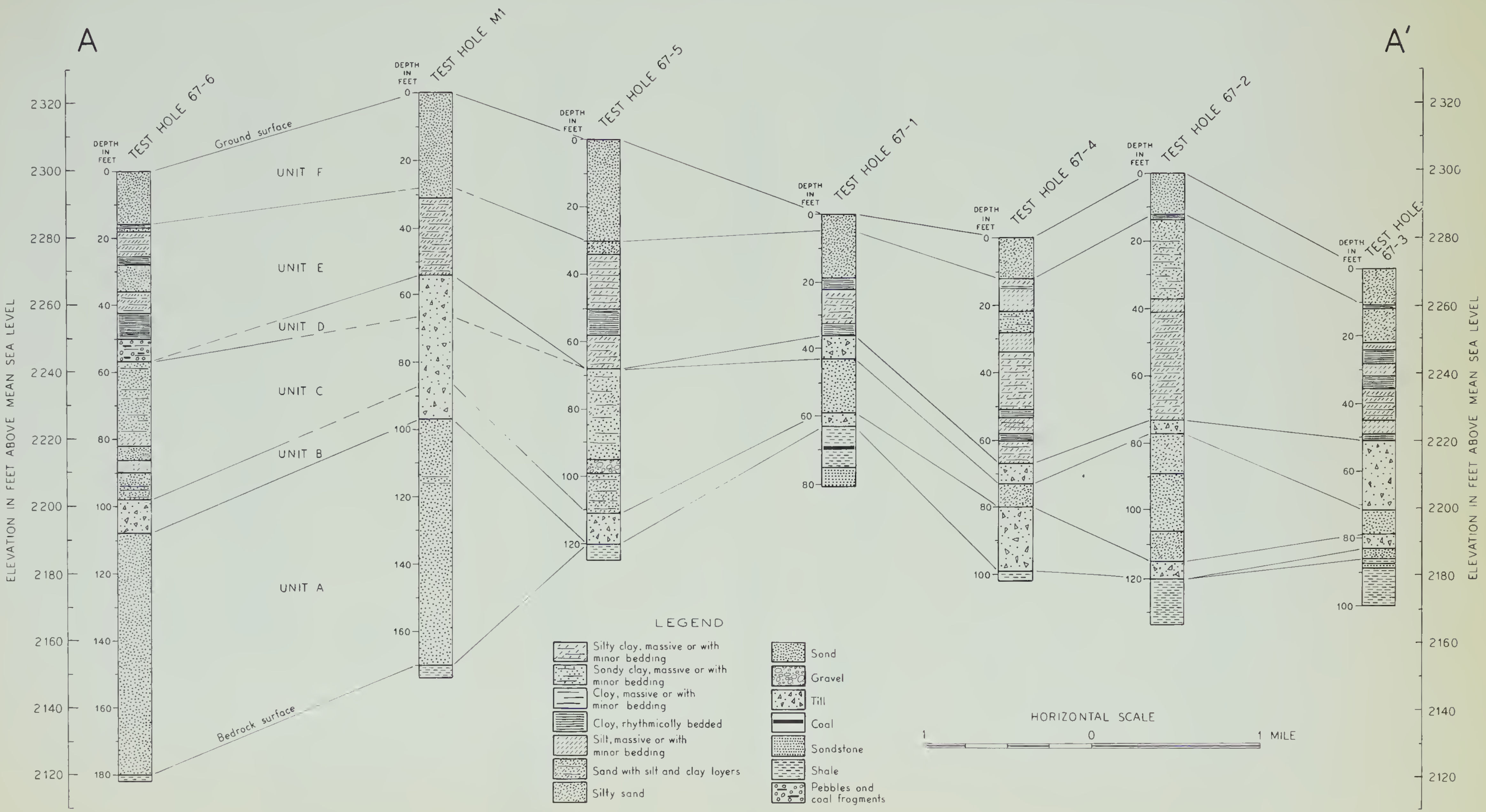


Figure 5. Geologic cross section A–A′ and graphic logs of test holes

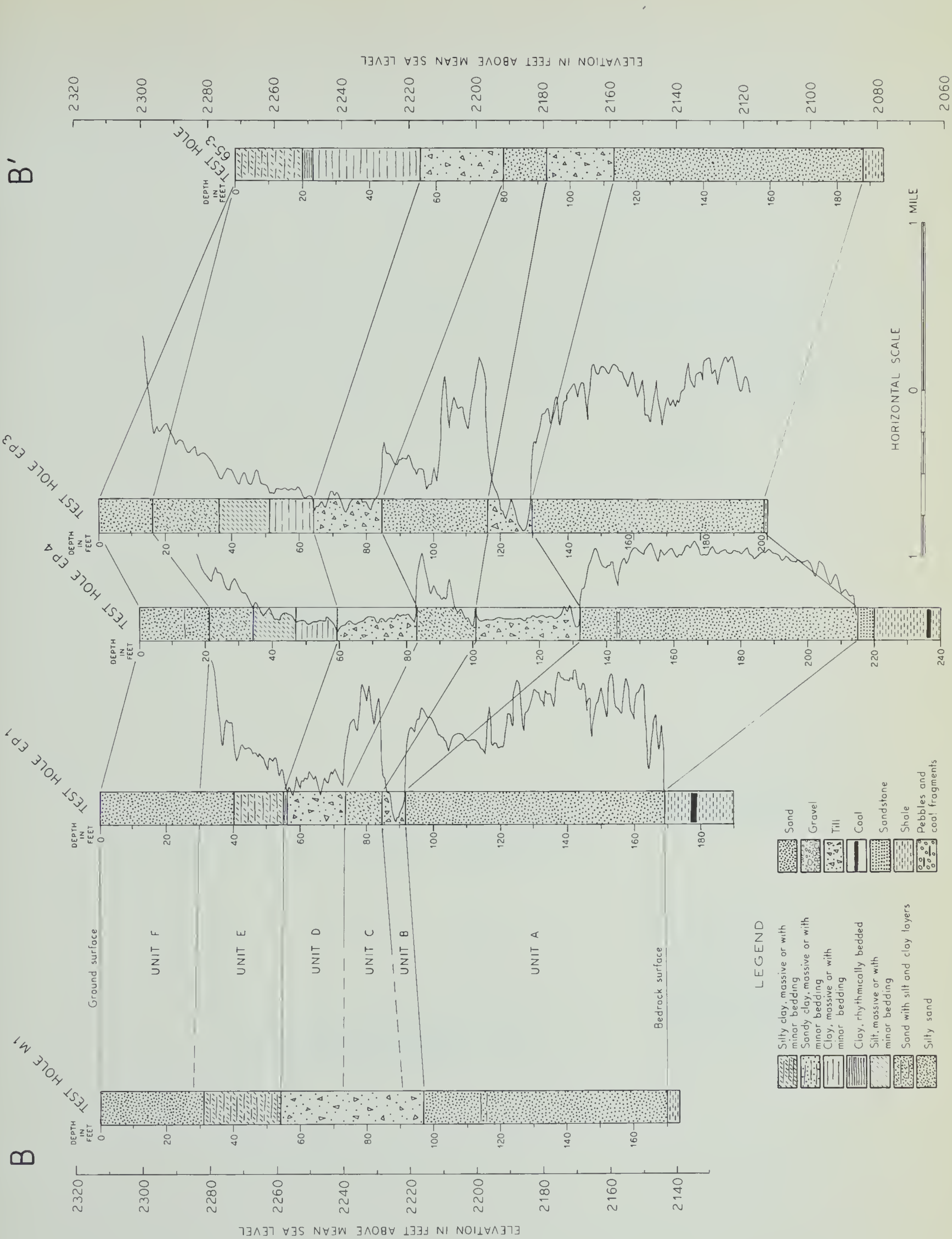


Figure 6. Geologic cross section B–B′, resistivity logs, and graphic logs of test holes

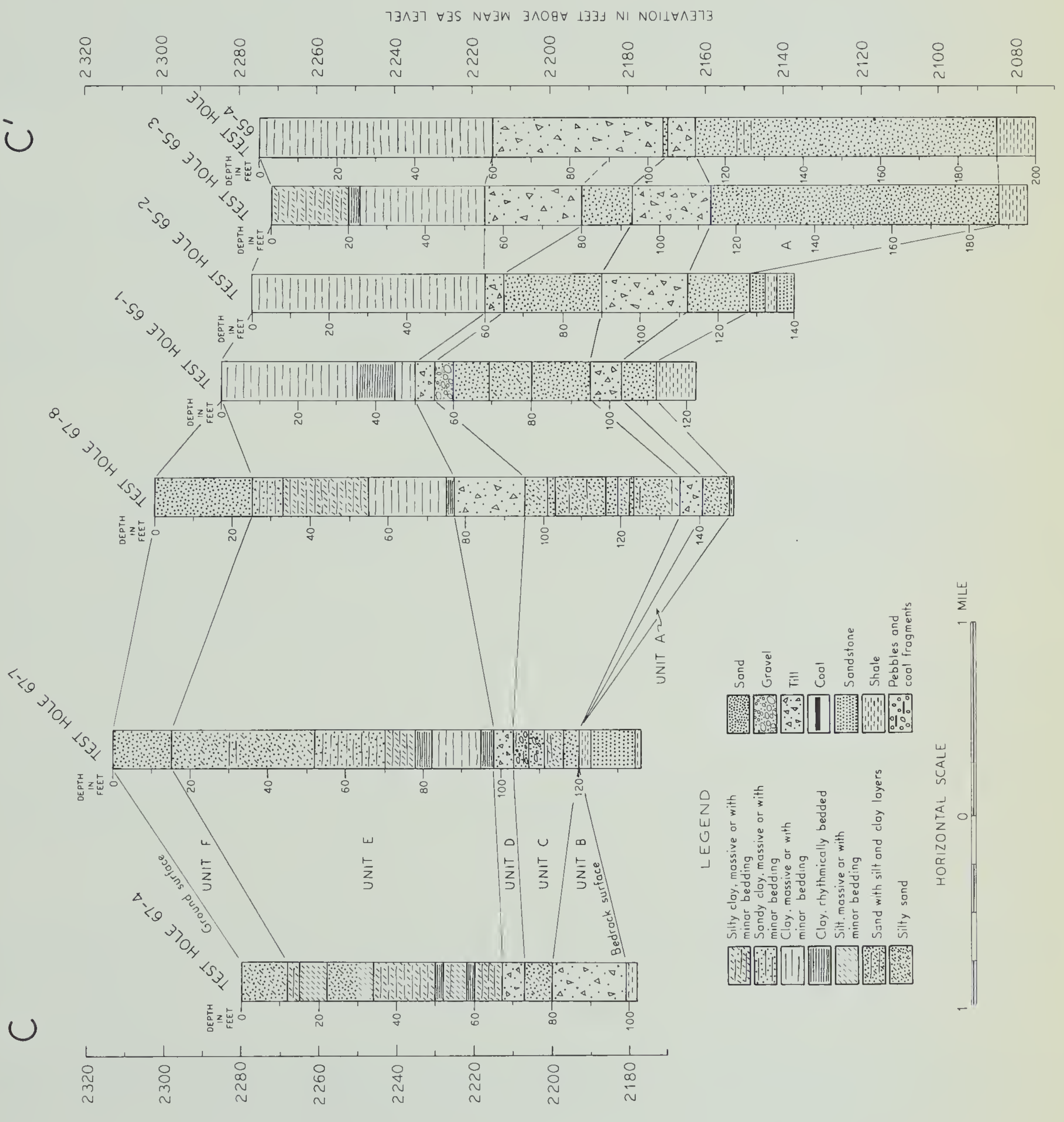


Figure 7. Geologic cross section C–C' and graphic logs of test holes

A section of surficial deposits exposed along the North Saskatchewan River was described and sampled using standard stratigraphic techniques. The location is shown on figure 4. This outcrop was selected for study after completion of the test drilling because it contained the complete sequence of deposits encountered in test holes drilled in the area. Graphic logs of the North Saskatchewan River section are shown on figure 8.

The surficial deposits were divided into six units designated by the letters A to F. The Units are essentially rock stratigraphic units. Unit A is the oldest deposit overlying bedrock material and Unit F is the youngest. A view of the outcrop (Plate 2a) shows the stratigraphic positions of the units of the surficial deposits.

Laboratory Analysis

The color, texture, and carbonate content of selected samples of each unit were determined in the laboratory. The pebble composition of bulk samples of till in Unit D was also determined and is summarized in Appendix E.

The color of dry, oxidized samples of the surficial deposits was established in addition to field determinations of the color of wet, unoxidized samples which are described in Appendix C for the test holes drilled in 1967.

Grain size analysis of material consisting of a high percentage of clay was done by the hydrometer method following a procedure based on A.S.T.M. standards (1964) and used by the Department of Geology, University of Alberta. The grain size distribution of sands was determined by sieve analysis using standard U.S. sieve sizes. Hydrometer and sieve analyses are found in Appendices A and B, respectively. The grain size distribution of deposits in Units B, D, E, and F is plotted for the North Saskatchewan River section and for each test hole drilled in 1967, so that

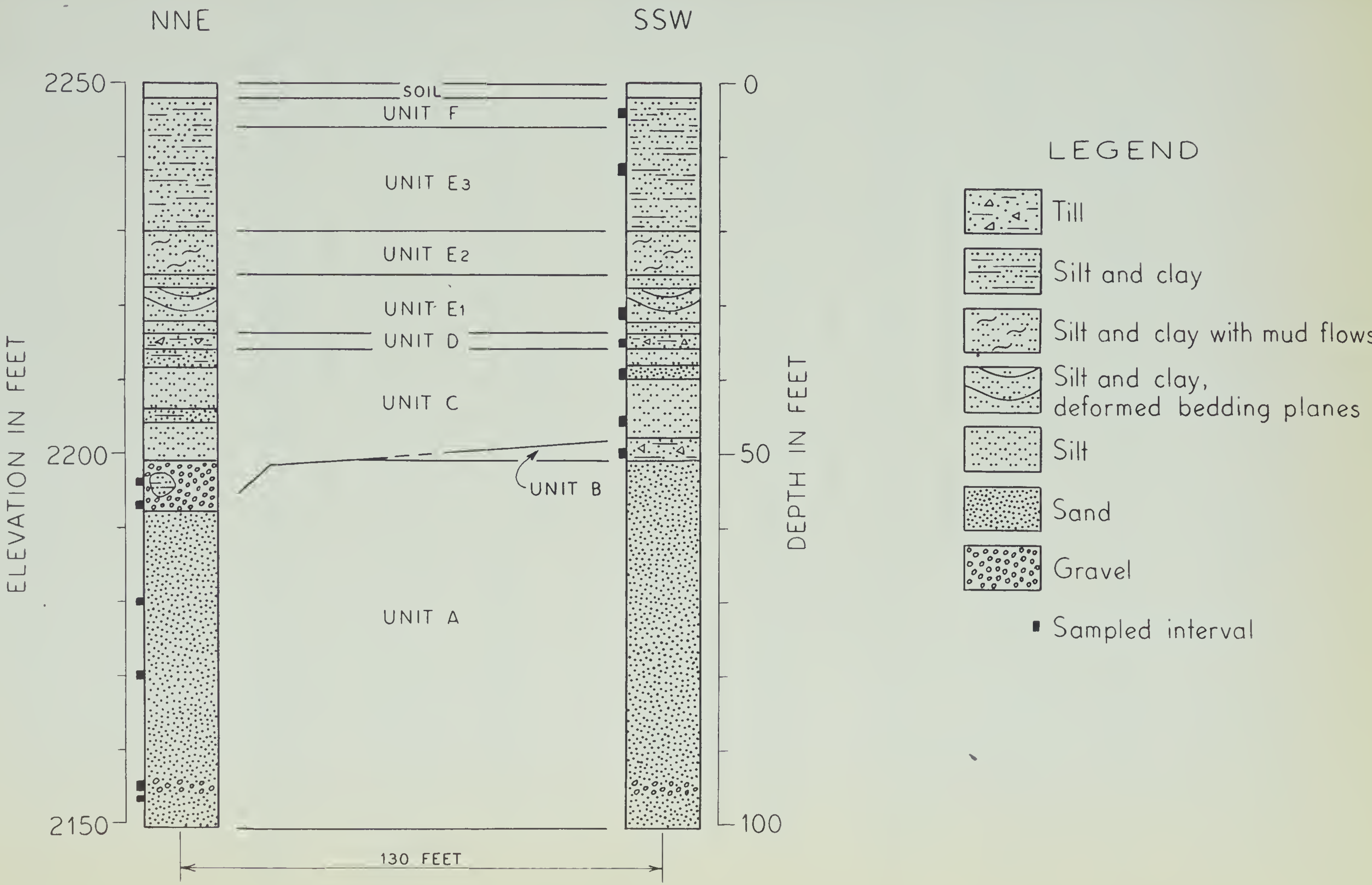


Figure 8. Graphic logs of the North Saskatchewan River section

the textural characteristics and relationships of the deposits can be seen more clearly. This information is represented in figures 13 to 21. The range of grain size distributions for samples in Units A and C is plotted on figures 9 and 22, respectively.

Statistical parameters of grain size described by Folk (1959) were calculated for the surficial deposits. The properties of sediments in each unit of the surficial deposits are described by comparing grain size parameters determined in the laboratory with scales of values for the parameters given by Folk. Definitions of the statistical parameters, scales of values, and determined grain size parameters for the units of the surficial deposits are tabulated in Appendix D.

Carbonate content of the surficial deposits (-200 mesh) was measured using the gasometric Chittick device and following the procedure outlined by Dreimanis (1962). Percentage values of carbonate present in the various units are listed in Appendix F.

Bedrock Deposits

The surficial deposits in the area are underlain by Upper Cretaceous Edmonton Formation. Ower (1958) divided the Edmonton Formation into five members of which the lowest member subcrops in the area. This member consists of alternating bentonitic, carbonaceous shales and light grey salt and pepper sandstones. Ironstone bands and concretions are common. Numerous coal seams are also present.

Petrography and Stratigraphy of the Surficial Deposits

Unit A

Unit A is the Saskatchewan gravels and sands on the basis of accepted criteria for identifying this group of sediments (Stalker, 1968). Allong (1967) identified the sands in test holes 65-1 and 65-2 (Figs. 4 and 7) as Saskatchewan gravels and sands by a heavy mineral analysis. He also suggested local bedrock and adjacent Tertiary gravels as the source of these deposits.

Recent studies of the Saskatchewan gravels and sands have bracketed the age limits of these deposits in the Edmonton area. Westgate and Bayrock (1964), from a study of periglacial structures in gravels and sands, concluded that the sediments are older than "classical Wisconsin" but are certainly of Pleistocene age. Reimchen (1968), in a study of the paleontology and stratigraphy of the Saskatchewan gravels and sands in Alberta, suggested that the maximum possible age for overlying glacial drift in the central Alberta region is Illinoian.

In the study area Unit A lies unconformably on the Upper Cretaceous bedrock of the Edmonton Formation and is comprised almost entirely of sand. The sand was deposited in terraced valleys on the bedrock surface. Boundaries of the main valley in the area are outlined on figure 4 and locations of other valleys are shown on figure 3. The maximum thickness of sands filling the main buried valley was found to be 83 feet at test hole EP4 (Figs. 4 and 6). Sediments of Unit A occurring in the outcrop (Fig. 8), in test hole 67-3 (Fig. 5), the Des Lauriers and Schafer wells (Appendix C), and test hole E9 (Appendic C) are situated in the Devon Valley (Carlson, 1967).

Dry, oxidized samples of the sands are light olive grey in color (5Y 5.5/1 to

5Y 6/1.5). The sand is stained a red ocher color at the outcrop, particularly in the lower few feet. This coloring is due to the precipitation of iron oxide from groundwater discharging and evaporating at the surface of the outcrop.

The sands in the lowest part of the major buried valley are poorly sorted, coarse-skewed, very leptokurtic, and have mean diameters of less than 2.00 phi. These characteristics are particularly true for the lower 10 to 20 feet of Unit A.

The upper part of the sands range from moderately sorted to moderately poorly sorted, mesokurtic to leptokurtic, near-symmetrical to fine-skewed, and have mean diameters larger than 2.00 phi.

Typical grain size distribution of sediments in Unit A are shown for selected samples in figure 9. The samples were selected to show the range of grain size in the sands. Prominent pebble and gravel layers composed mainly of clay ironstone concretions are also present in the lower portion of the sands (Plate 2b). The pebble composition of a gravel layer in the sands in the river section, excluding concretions and local bedrock material is shown on figure 10. No Precambrian Shield rock-types were found in the sands.

An examination and comparison of geologic cross sections A-A' (Fig. 5), B-B' (Fig. 6), C-C' (Fig. 7), and Carlson's map of thalwegs of preglacial valleys, suggest rather strongly that the buried valley outlined on figure 4 is a main tributary to the Beverly Valley. The tributary probably continues westward along the bedrock low which crosses the lower part of Tp. 51, R. 27 (Carlson, 1967, Fig. 2c) instead of south to the Calmar Valley. Hydrologic evidence discussed later in this thesis adds weight to this conclusion.

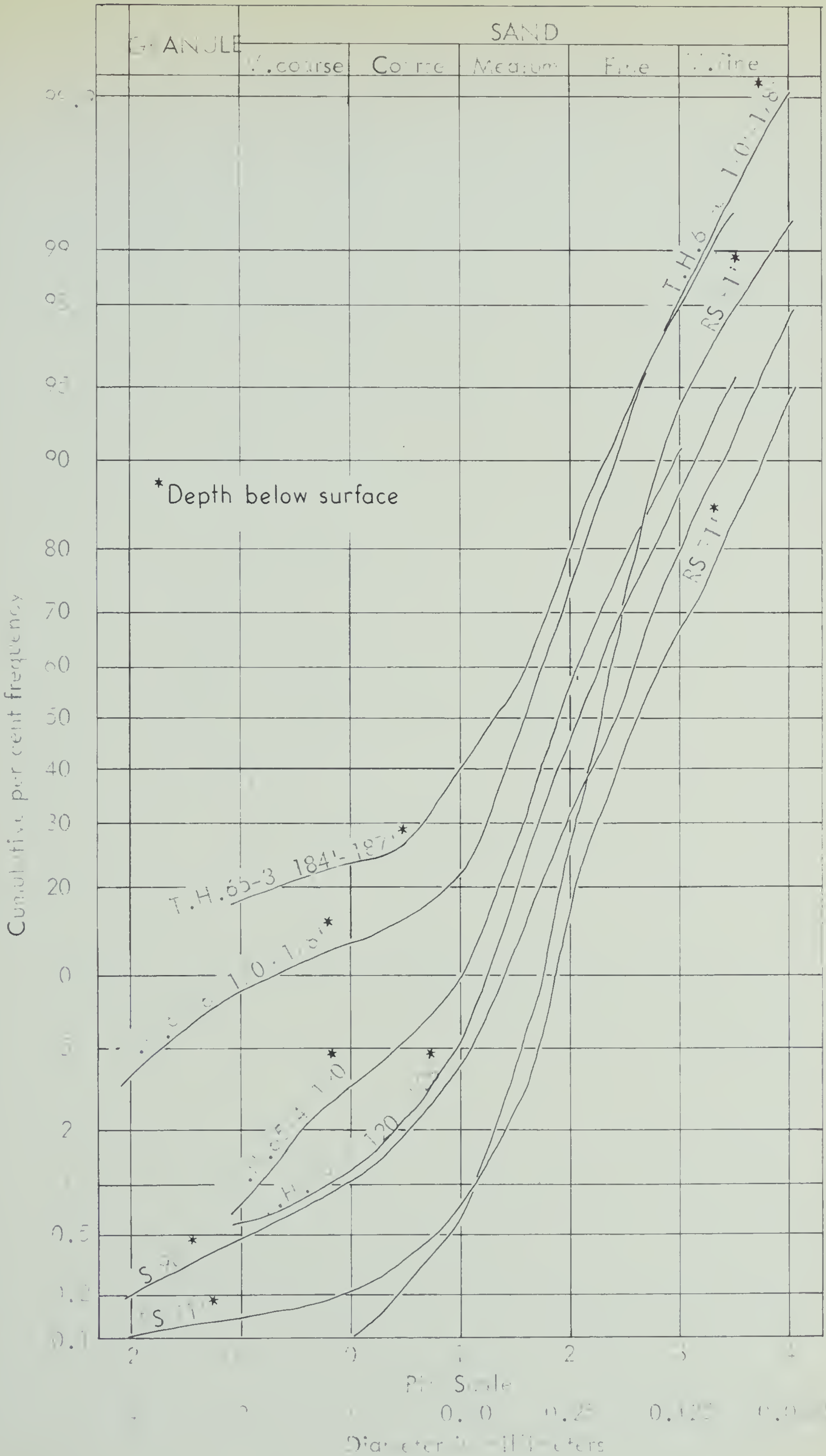


Figure 9. Range of grain size distribution of deposits in Unit A

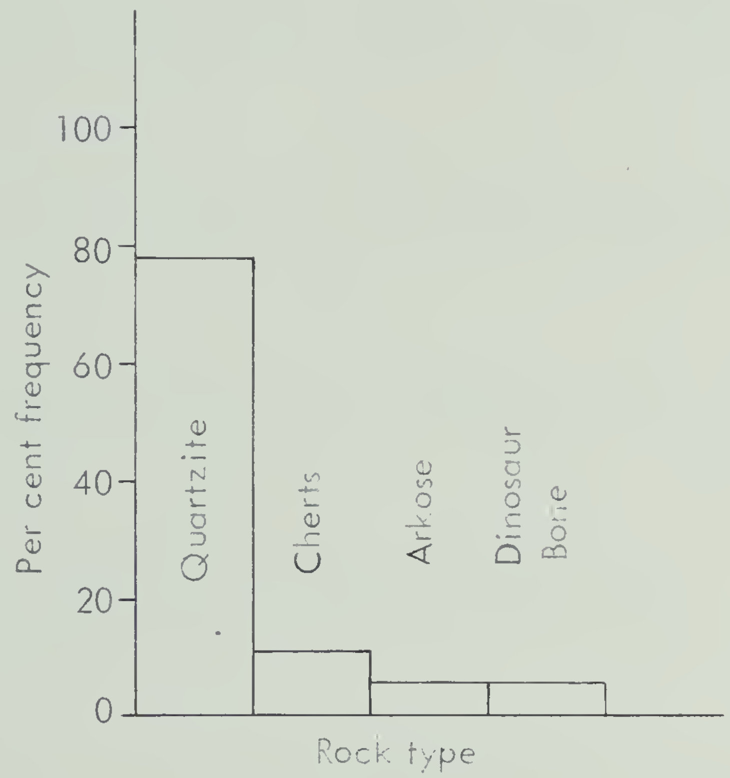


Figure 10. Composition of pebble layer near base of Unit A

Unit B

This unit is a till that overlies deposits of Unit A. The till is present over most of the area but is missing at some localities. The thickest deposits of the till were found at locations where major buried valleys are present on the bedrock surface (Fig. 6).

At the outcrop the unit has a pronounced blocky jointing, contains large granitic and gneissic boulders (Plate 3a), and has been eroded and dissected by glacial meltwater that deposited sediments of Unit C (Plate 3b). The deposits average about 2 1/2 feet in thickness. At the extreme left side of the section (Plate 2a) glacial meltwater cut a channel through deposits of Unit B into the top of Unit A (Plate 4a) and deposited gravel with a composition high in Precambrian Shield stones. Unit B overlies Unit A unconformably but no evidence could be found that would suggest a long break between the deposition of the two units.

The color of dry, oxidized samples is olive grey (5Y 4.5/1 to 5Y 6.5/1).

Texturally, Unit B ranges considerably (Fig. 11). At the river section and test hole 67-1 the unit is a clay loam but is a loam, sandy clay loam, or sandy loam at the site of other test holes with the exception of test hole 67-7 where the unit is missing. The till of Unit B has a wider range in grain size distribution than the younger till -- Unit D (Fig. 12).

An inspection of figures 13 to 21 and figure 11 visually demonstrates the textural relationship of Unit B to other material in the surficial deposits. Notably the grain size distribution parallels that of Unit D. The deposits in Unit B are extremely poorly sorted and strongly fine-skewed.

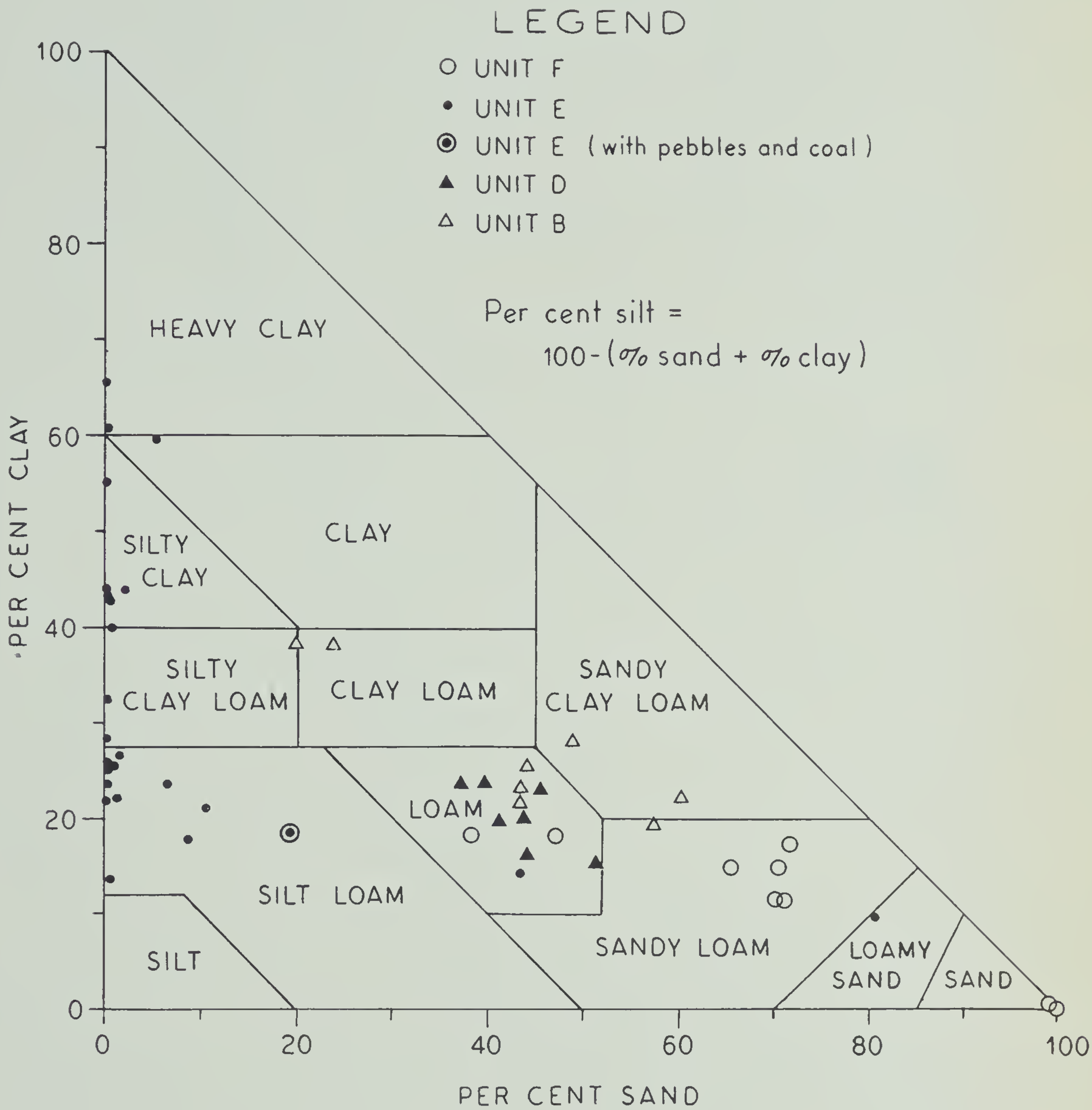


Figure 11. Textural classification of deposits in Units B, D, E, and F (Textural classification used by Soil Science Department, University of Alberta)

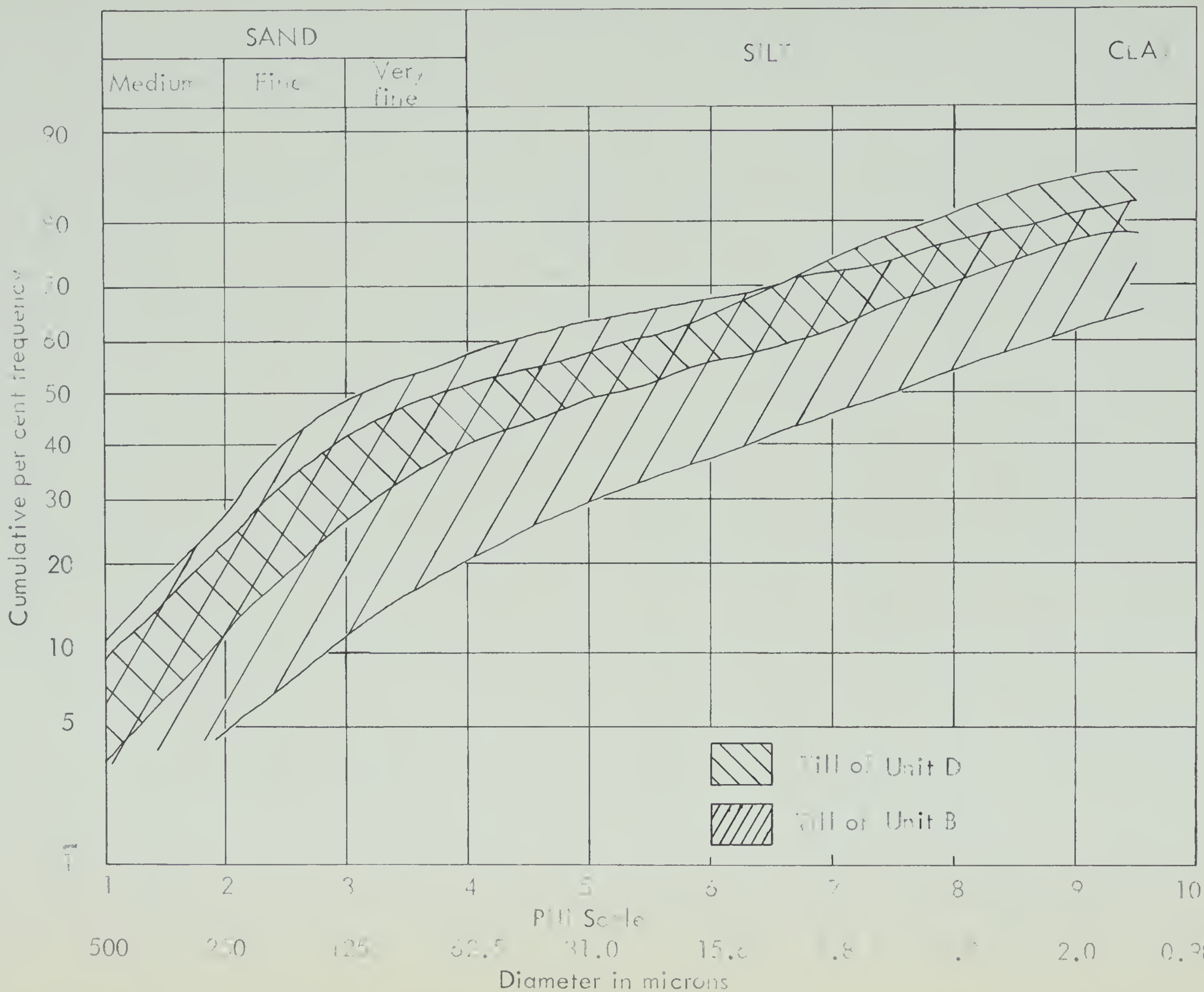


Figure 12. Range of grain size distribution of tills in Units B and D

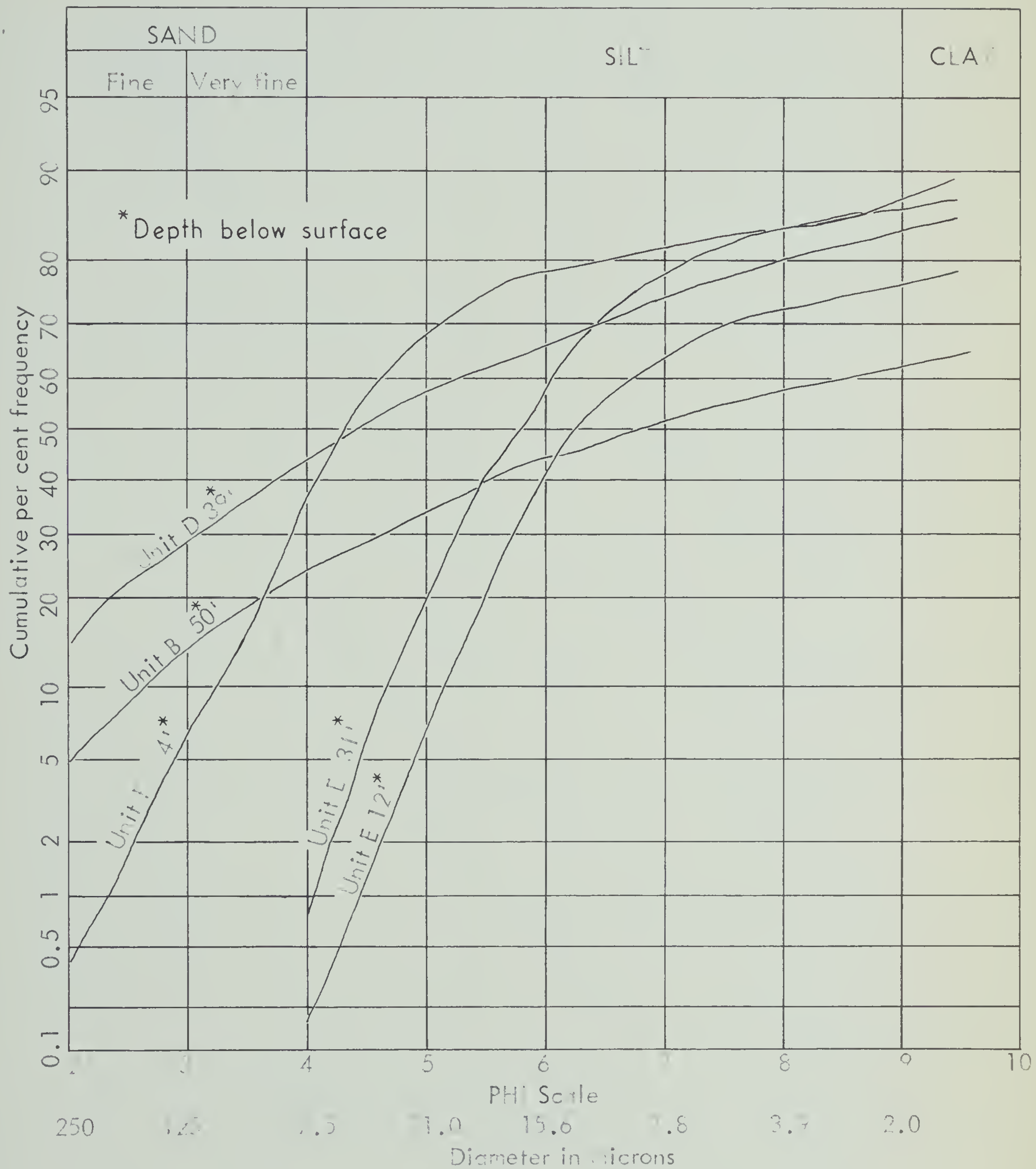


Figure 13. Grain size distribution of deposits in Units B, D, E, and F
at the North Saskatchewan River section

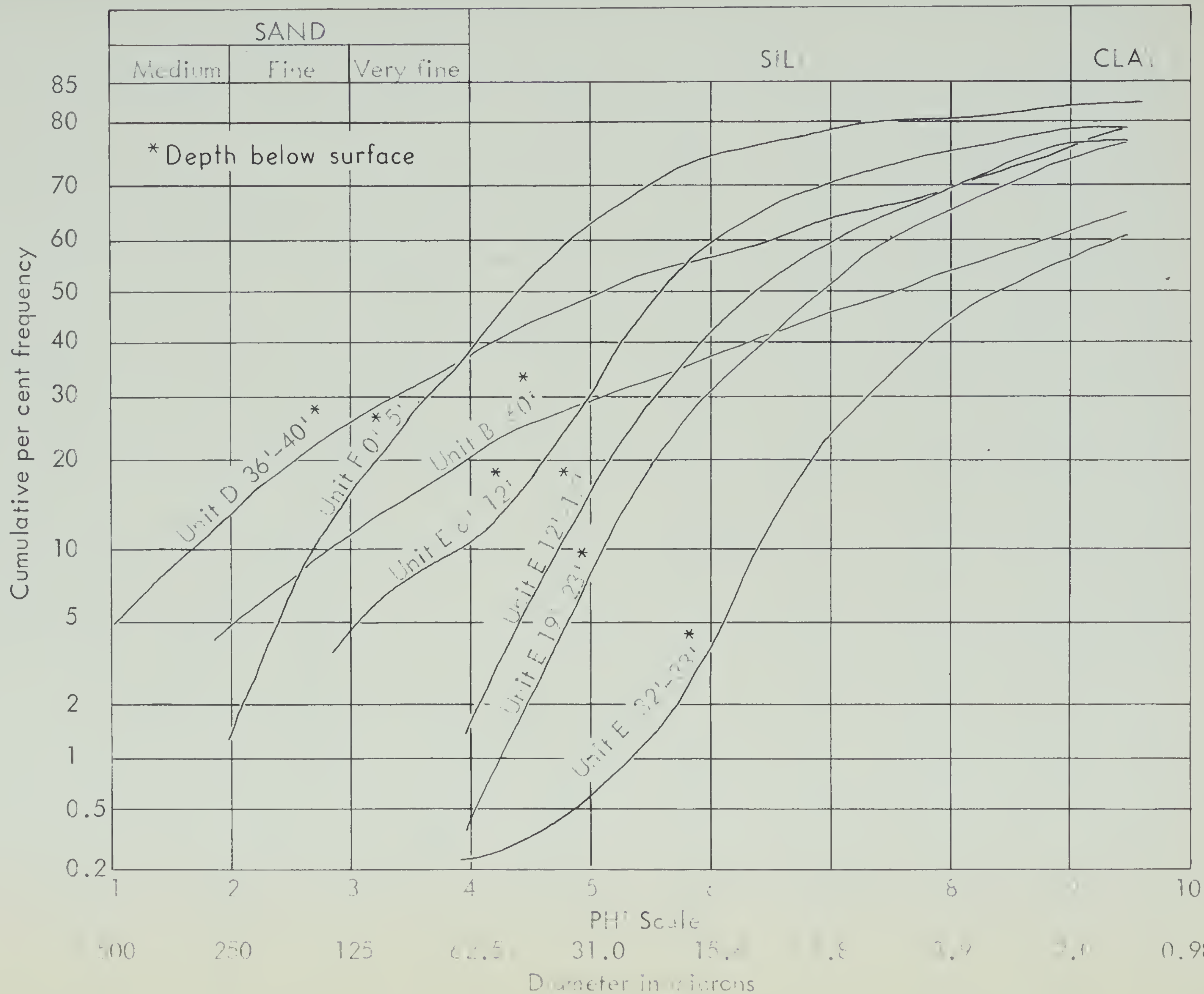


Figure 14. Grain size distribution of deposits in Units B, D, E, and F at test hole 7-1

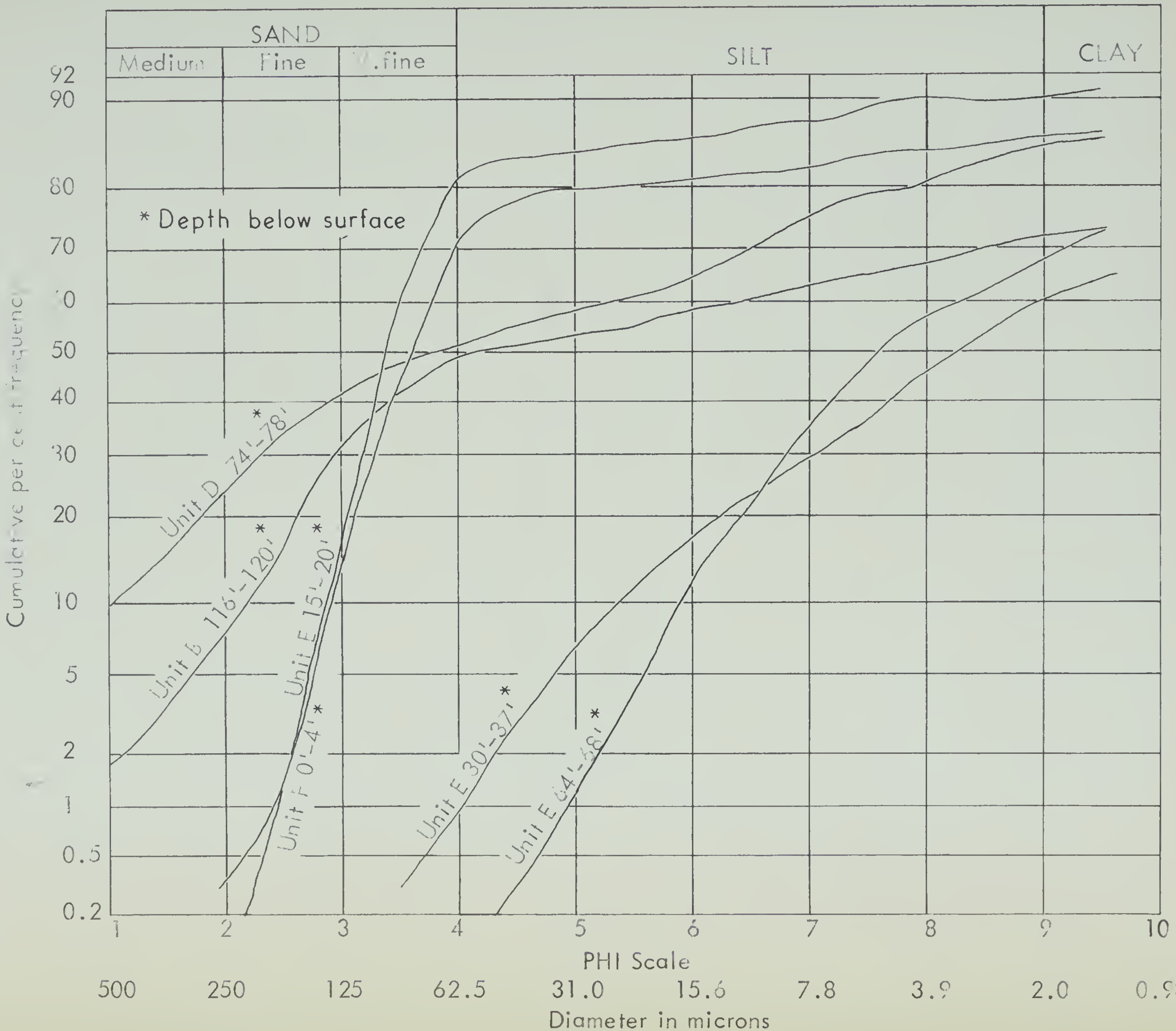


Figure 15. Grain size distribution of deposits in Units B, D, E, and F at test hole 67-2

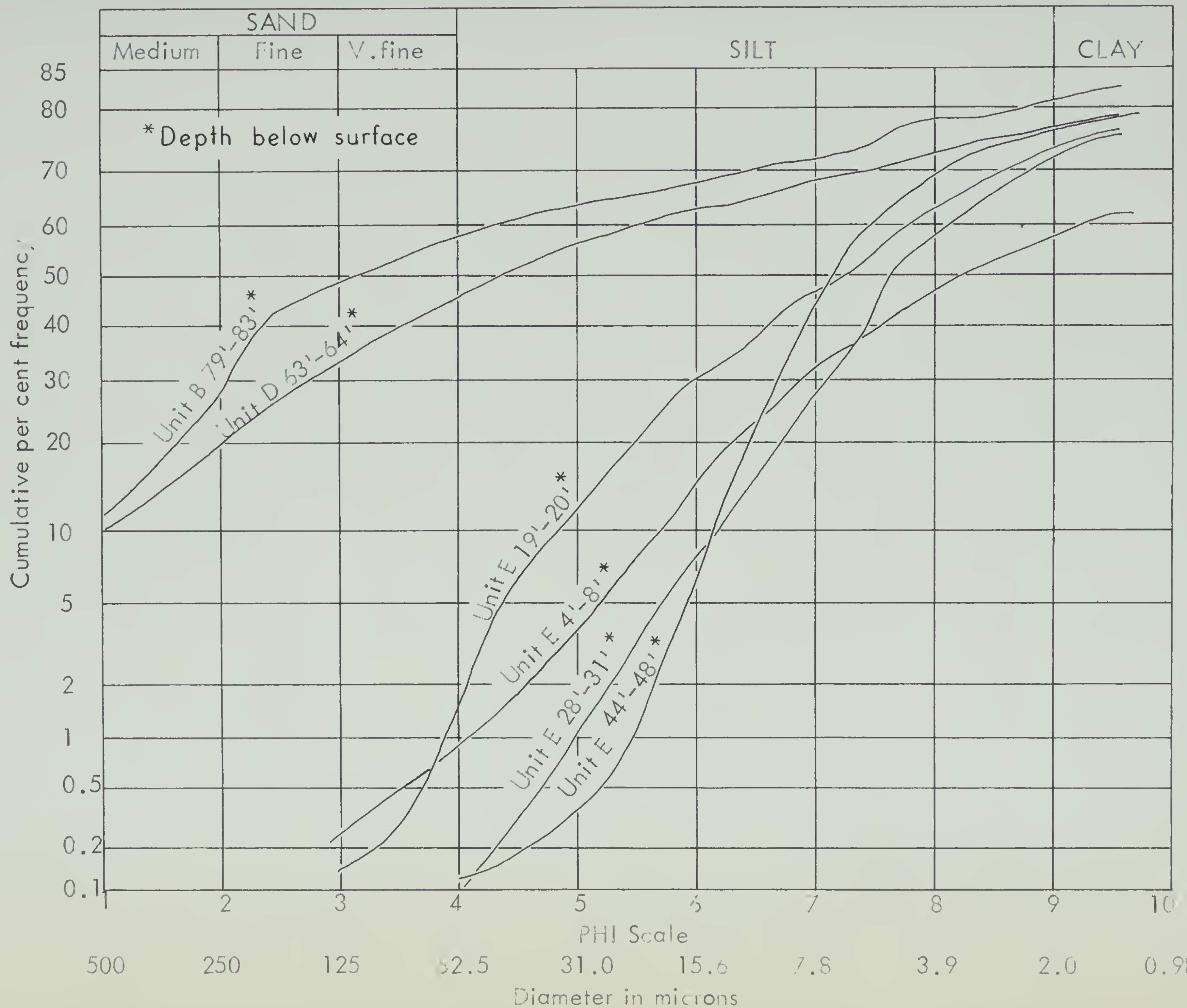


Figure 16. Grain size distribution of deposits in Units B, D, and E at test hole 67-3

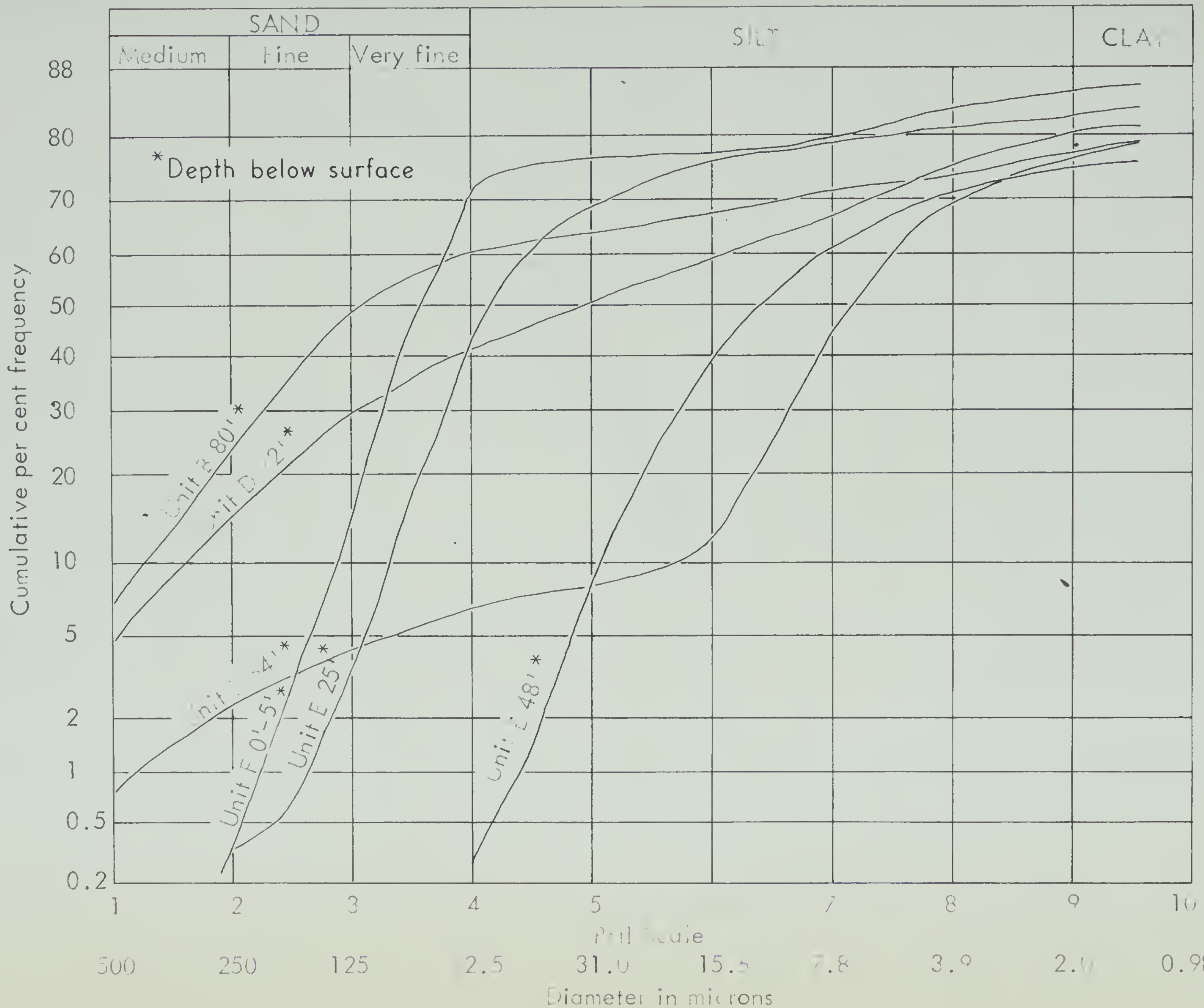


Figure 17. Grain size distribution of deposits in Units B, D, E, and F at test hole 67-4

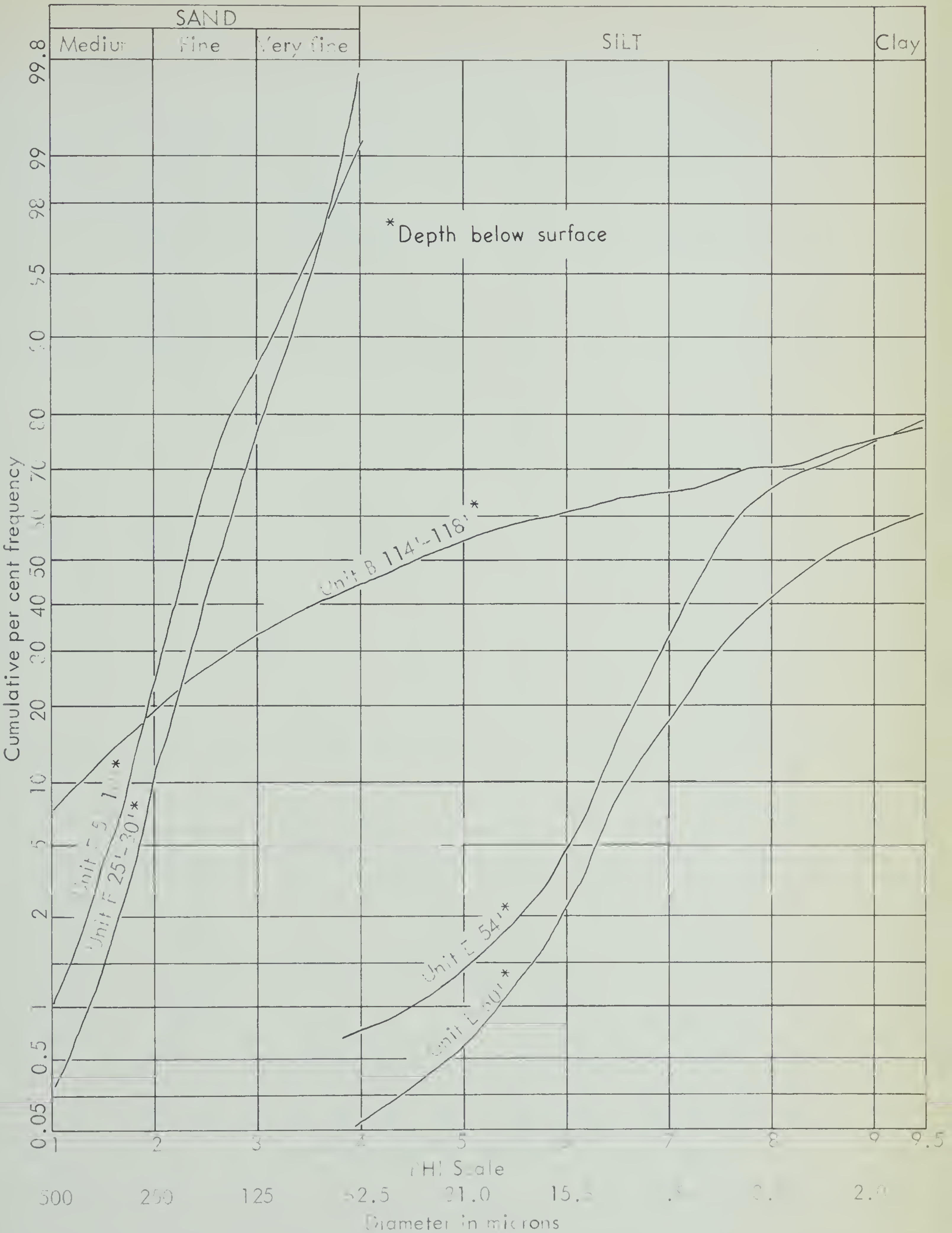


Figure 18. Grain size distribution of deposits in Units B, E, and F at test hole 67-5

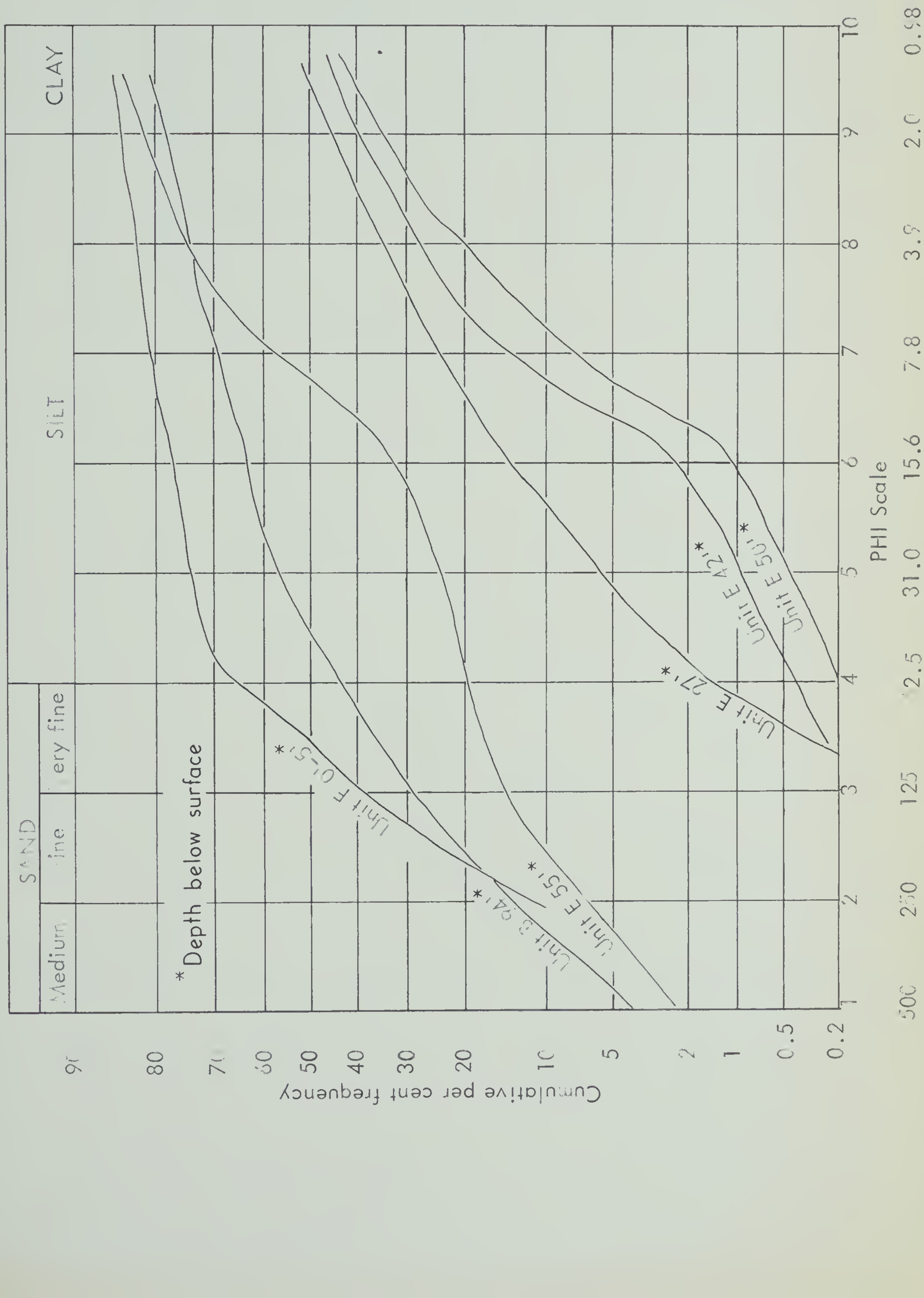


Figure 19. Grain size distribution of deposits in Units B, E, and F at test hole 67-6

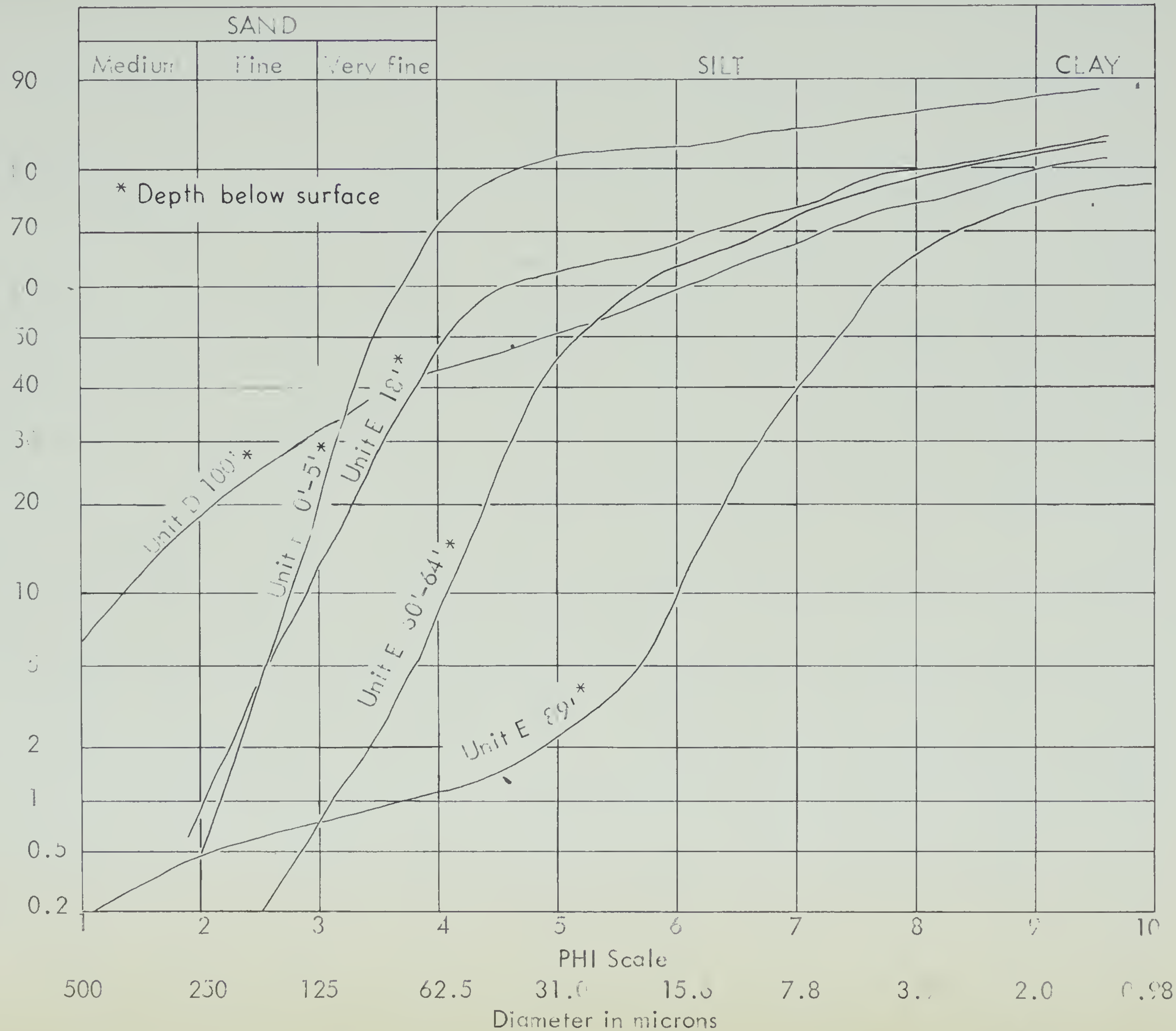


Figure 20. Grain size distribution of deposits in Units D, E, and F at test hole 57-7

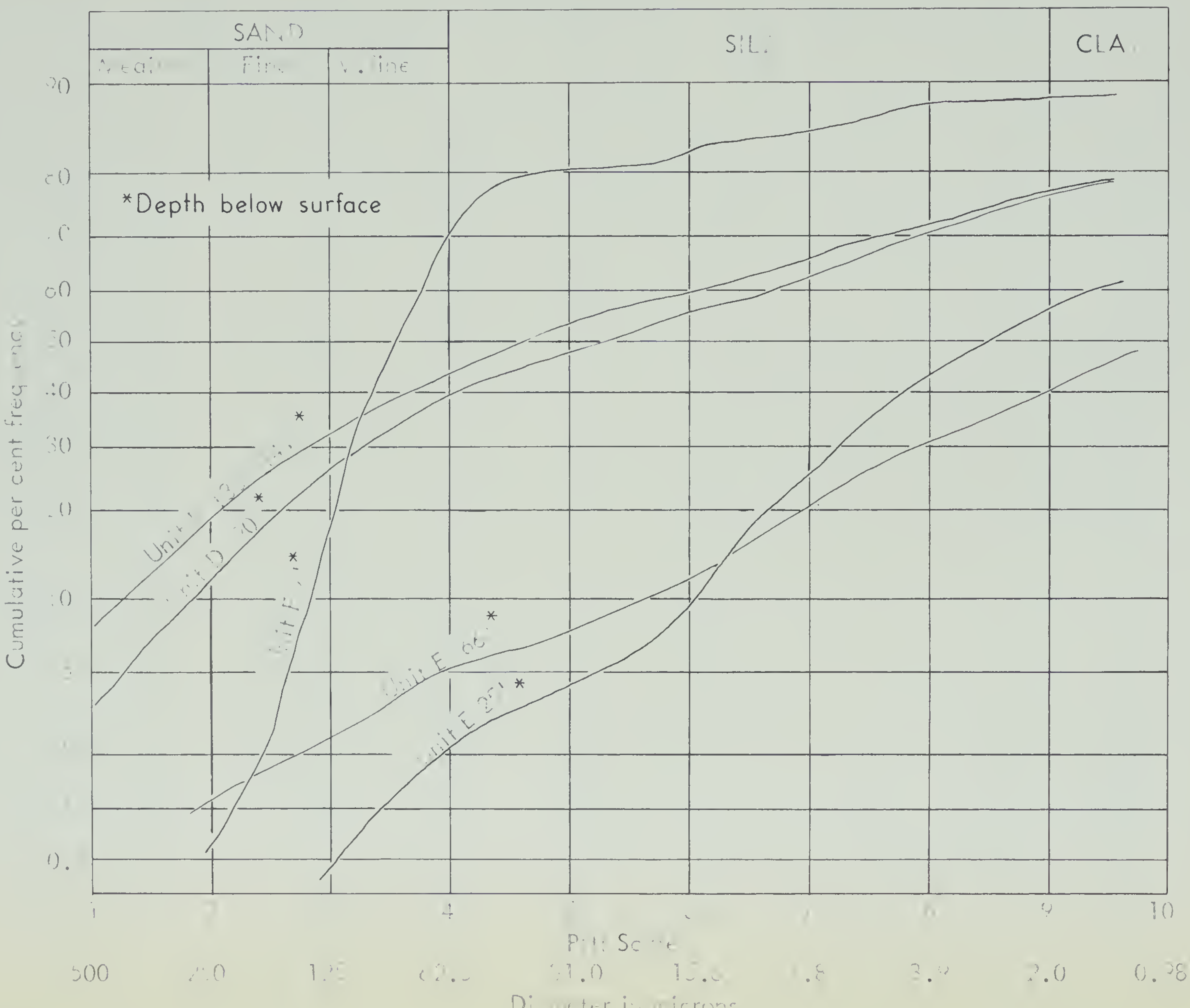


Figure 21. Grain size distribution of deposits in Units B, D, E, and F at test hole 67-8

The carbonate content of the matrix (-200 mesh) of Unit B (Appendix F) is only a few per cent with an 8 sample average of 3.8 per cent. The average calcite to dolomite ratio is 0.52.

The striking feature of drill cuttings of this till is the high percentage of included bedrock material. Where the deposits are only a few feet thick and overlie bedrock, samples must be taken with the utmost care and examined meticulously before identification. A comparison of data obtained from test hole 67-6 and shot-hole logs at the same site suggest that some seismic drilling crews have identified this deposit as bedrock. This explains anomalies at locations such as Sec. 13, Tp. 50, R. 26, W. 4, on Carlson's map (Fig. 3) in respect to the buried valley location on figure 4.

Resistivity logs reproduced in figure 6 very obviously suggest that the boundaries of Unit B, as well as those of other units of the surficial deposits, can be picked from the E-logs locally, particularly when the expected sequence of deposits is known from other test holes drilled and sampled in the area.

Continuous till deposits are reported in test holes M1 and 65-4 which were drilled with rotary rigs. It is doubtful if this is actually the case since all the holes drilled by the writer with a cable-tool rig or holes E-logged after being drilled with a rotary rig show the tills of Units B and D are separated by a predominantly sand deposit.

<u>Unit C</u>

Unit C sediments were deposited in a glaciofluvial environment. The sediments include gravel, well-bedded sands, and massive, sandy silts. Stratigraphically the deposits of the unit are underlain by the deposits of Unit B and overlain by deposits of Unit D, except where one or both of these units is absent.

The sediments were present in all test holes drilled in the area and range

from a few feet to 40 feet in thickness. Gravel in the glacial meltwater channel at the outcrop (Plate 4a) contains abundant Precambrian Shield rocks, numerous concretions, bedrock fragments, and quartzite stones. The gravels also contain a large block of bedded silt (Plate 4b) which clearly must have been frozen to remain intact after it was laid down. The position of the block of silt can be seen at the extreme left in Plate 4a using the prominent inclusion of coal as a reference.

Texturally the sands of Unit C are moderately sorted to moderately poorly sorted but poorly sorted materials are also present. The materials are predominantly coarse-skewed with a few samples being near-symmetrical. Only 3 samples out of 21 were not leptokurtic. A fraction of the fines from drill samples was probably lost during the washing of samples but bulk samples obtained do not show statistical parameters strikingly different from the washed samples. Figure 22 shows the range of grain size distribution for selected samples of deposits in Unit C. The bulk samples are all included.

The most notable difference in gross composition and texture between deposits of Unit C and Unit A is that the former deposits contain Precambrian Shield material and are coarse-skewed whereas the latter contain no Precambrian Shield stones and are predominantly fine-skewed. Considerable fragmentary coal is present throughout the deposits of Unit C.

Unit D

Unit D is a till which stratigraphically is overlain by well-bedded deposits of Unit E. The till is only a few feet thick over much of the area but reaches a maximum thickness of 20 to 25 feet. The thicker deposits were usually encountered where valleys are present on the bedrock surface (Figs. 5, 6, and 7). The unit is not

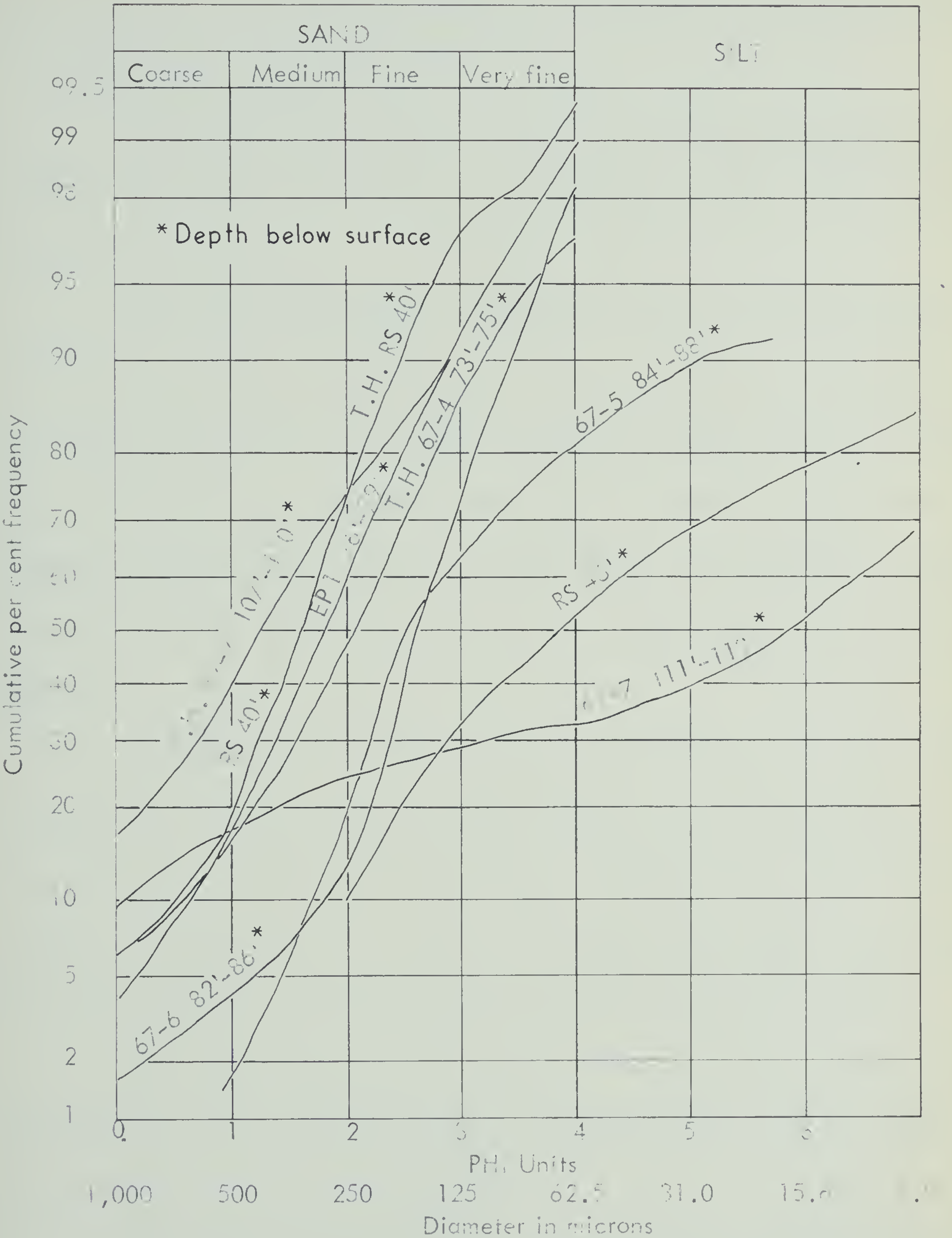


Figure 22. Range of grain size distribution of deposits in Unit C

present at test holes 67-5 and 67-6 but at 67-6 the lower part of the overlying unit is well-bedded material containing abundant pebbles, concretions, and coal fragments (Fig. 5). In the outcrop studied the till is a 2-foot thick massive unit with a well developed columnar jointing (Plate 5).

The color of Unit D appears somewhat lighter than Unit B at the outcrop, but the color (5Y 5/1) is much the same for dry, oxidized samples of both tills taken from test holes in the area.

The grain size distributions of deposits in Unit D are plotted on figures 13 to 17, 20 and 21. The deposits of the unit are very poorly sorted and strongly fine-skewed. Texturally the till is rather uniform and can be classified as a loam (Fig. 11). The range in grain size distribution for the deposits is very restricted compared to deposits of Unit B (Fig. 12). The material in test hole 67-6 is a silt loam (Fig. 11) and is texturally intermediate between till of Unit D and bedded silts of Unit E.

The analyses of the pebble composition of five bulk samples indicate the provenance of the material as the Precambrian Shield and local bedrock material (Appendix E). The till contains abundant coal. A fabric analysis of till in Unit D (Appendix G) was carried out in the field. The results of the analysis are plotted in figure 23 and indicate a northeast-southwest direction of transport for the till.

The carbonate content of the matrix (-200 mesh) of deposits in Unit D (Appendix F) is low, the average content for 7 samples being 5.1 per cent. The average calcite to dolomite ratio was 0.52.

The boundary between the till and overlying deposits of Unit E is a sharp one in the test holes where the map unit is present, as well as in the outcrop section.

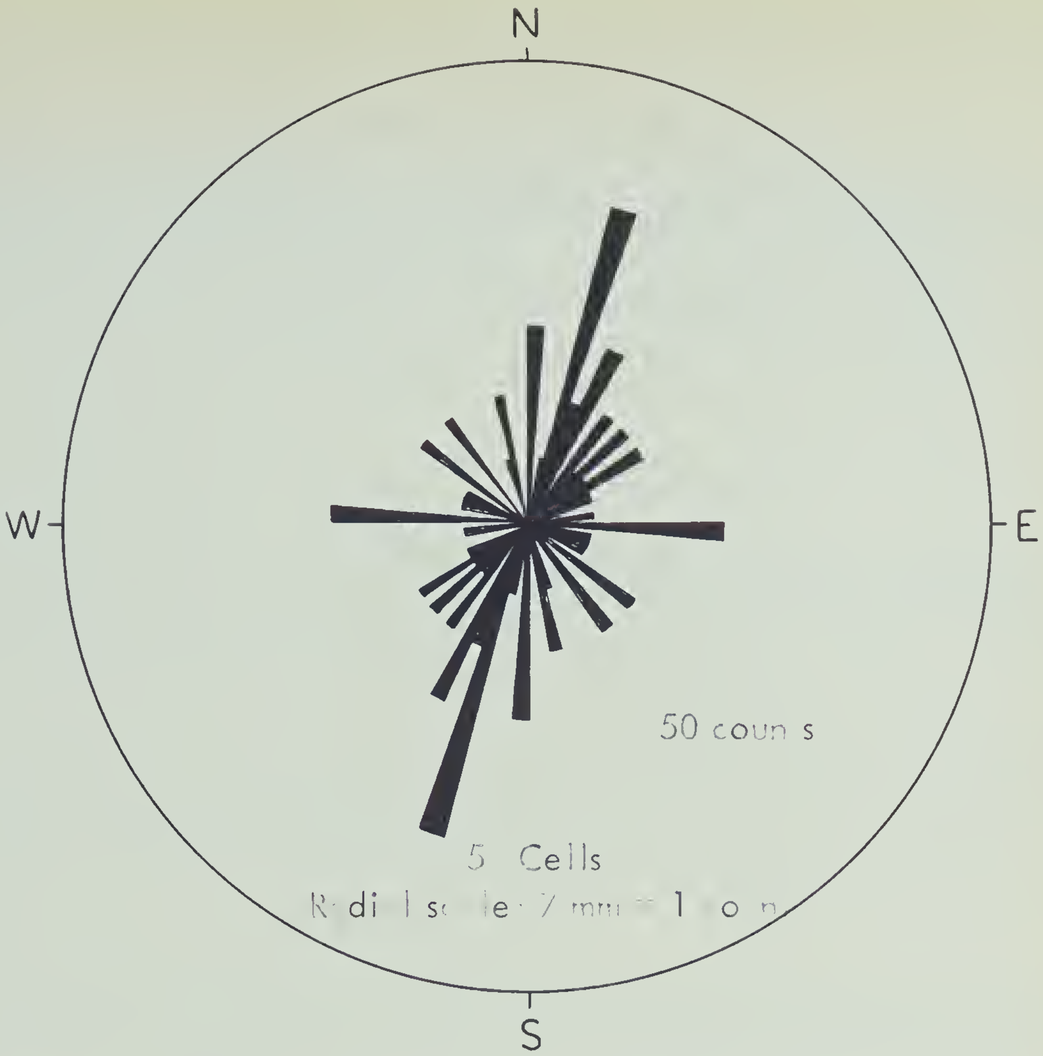


Figure 23a. Rose diagram showing long-axis orientation of stones in till of Unit D

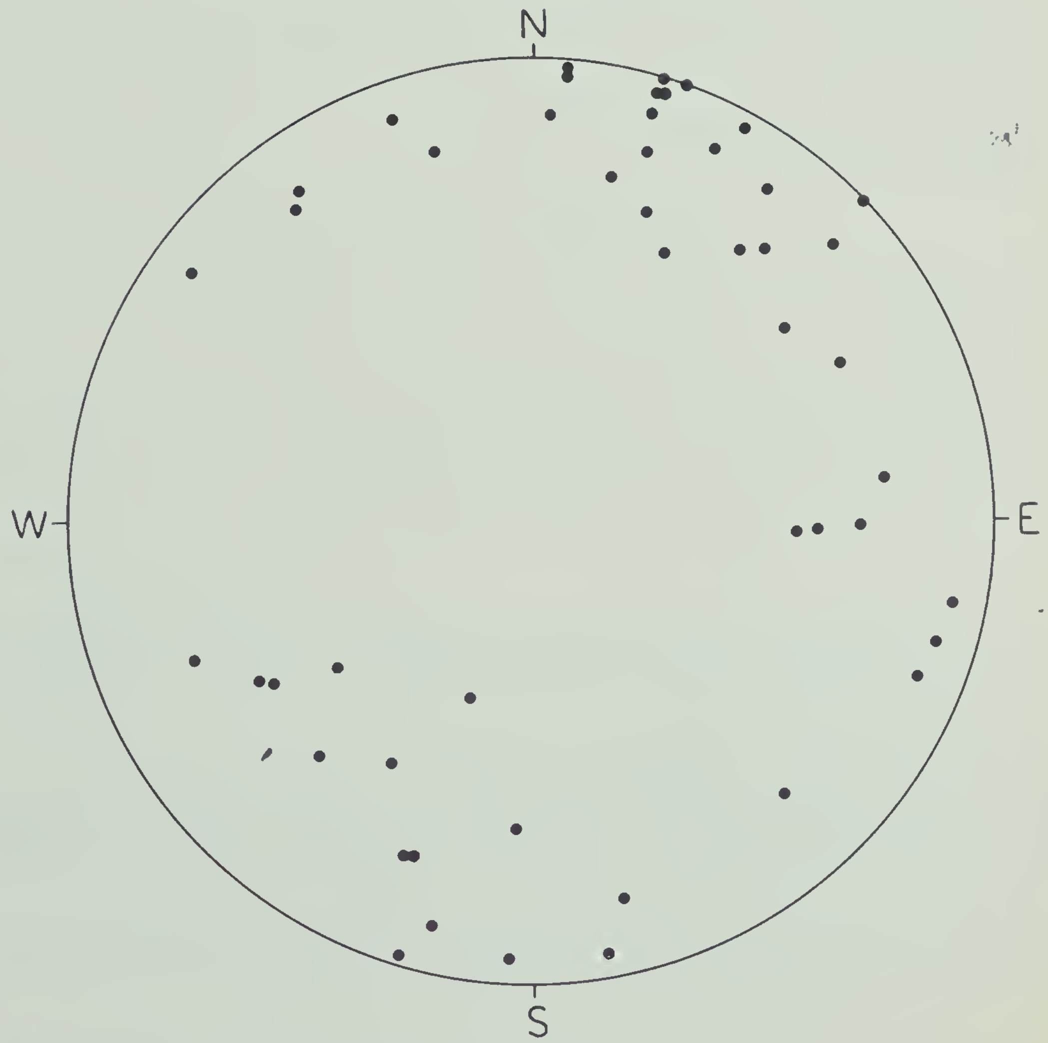


Figure 23b. Stereographic projection of the plunge angle of the long axis of stones in till of Unit D

The lower boundary between Unit D and Unit C is less distinct where silt forms the underlying bed but is well defined where the till overlies sand.

Excellent core samples were obtained of Unit D. The sharp boundary between Unit D and the overlying deposits of Unit E was found in a number of the cores (Plate 1b).

Unit E

Unit E deposits are predominantly very well bedded glaciolacustrine sands, silts, and clays of glacial Lake Edmonton (Bayrock and Hughes, 1962, p. 20-23). The sediments overlie till of Unit D and are overlain by aeolian sands of Unit F. The boundary between Unit E and Unit F has been taken as the top of the well bedded sequence. Unit E is present over the entire area.

At the outcrop section the deposits are about 28 feet thick and can be subdivided into three parts, E1 (lower), E2 (middle), and E3 (upper) (Fig. 8).

The lower part of the unit is characterized by well bedded materials which have been deformed by folding (Plate 6). The deformed beds are bounded below and above by 1 foot and 1.5 feet of massive silt, respectively.

The middle part of Unit E is poorly bedded and contains deposits of till-like material and stones (Plate 7a). The thickness of this material is about 4.5 feet. Much of the material present was probably carried and dropped from icebergs floating on glacial Lake Edmonton.

The upper part of Unit E consists of rhythmically-bedded sand and silt (Plate 7b). Each rhythmite consists of a massive loamy sand member and a darker colored, well bedded member containing more clay. The boundaries of the rhythmite members are distinguished by differential weathering, texture, structure, and

color. The variation in thickness of consecutive rhythmites from the top of the middle deposits to the base of the overlying unit is diagrammatically shown in figure 24. A number of primary structural features was noticed in the rhythmites. These structures could be used in investigations carried out to determine the direction of transport for the sediments.

In the test holes, Unit E could not be subdivided but well bedded deposits are present most frequently in the lower part of the unit. An inspection of figures 13 to 21 shows that the sediments become increasingly and progressively coarser from the base of the unit to the top, no doubt as glacial Lake Edmonton became shallower. In test holes 67-2, 67-3, and 67-6 a thin layer of well bedded clay existed at the top of Unit E. At test holes 67-1, 67-2, 67-4, 67-6, and 67-7 deposits of Unit E are very sandy and have a grain size distribution little different from the overlying aeolian deposits of Unit F. Bayrock and Hughes (1962, p. 24) noticed that a definite distinction between early North Saskatchewan River alluvium and sandy deposits of the last stage of Lake Edmonton could not be made in some localities. Their conclusion that the sands are present where Lake Edmonton deposits (Unit E) are thickest is borne out by the present study (Figs. 5, 7, 15, 17, and 20). At test hole 67-7 (Fig. 7) Lake Edmonton sediments have a total thickness of 83 feet.

The most common Munsell colors of the sediments (dry, oxidized samples) are 2.5Y 6.5/2 and 5Y 6.5/1.5.

Texturally, the deposits in Unit E can be classified as heavy clay, silty clay, silty clay loam, silt loam, loam, and a loamy sand (Fig. 11). Silty clay loam and silt loam form the majority of the deposits, with heavy clay and silty clay in some areas. The silt loam, loam, and loamy sand are found in the upper part of

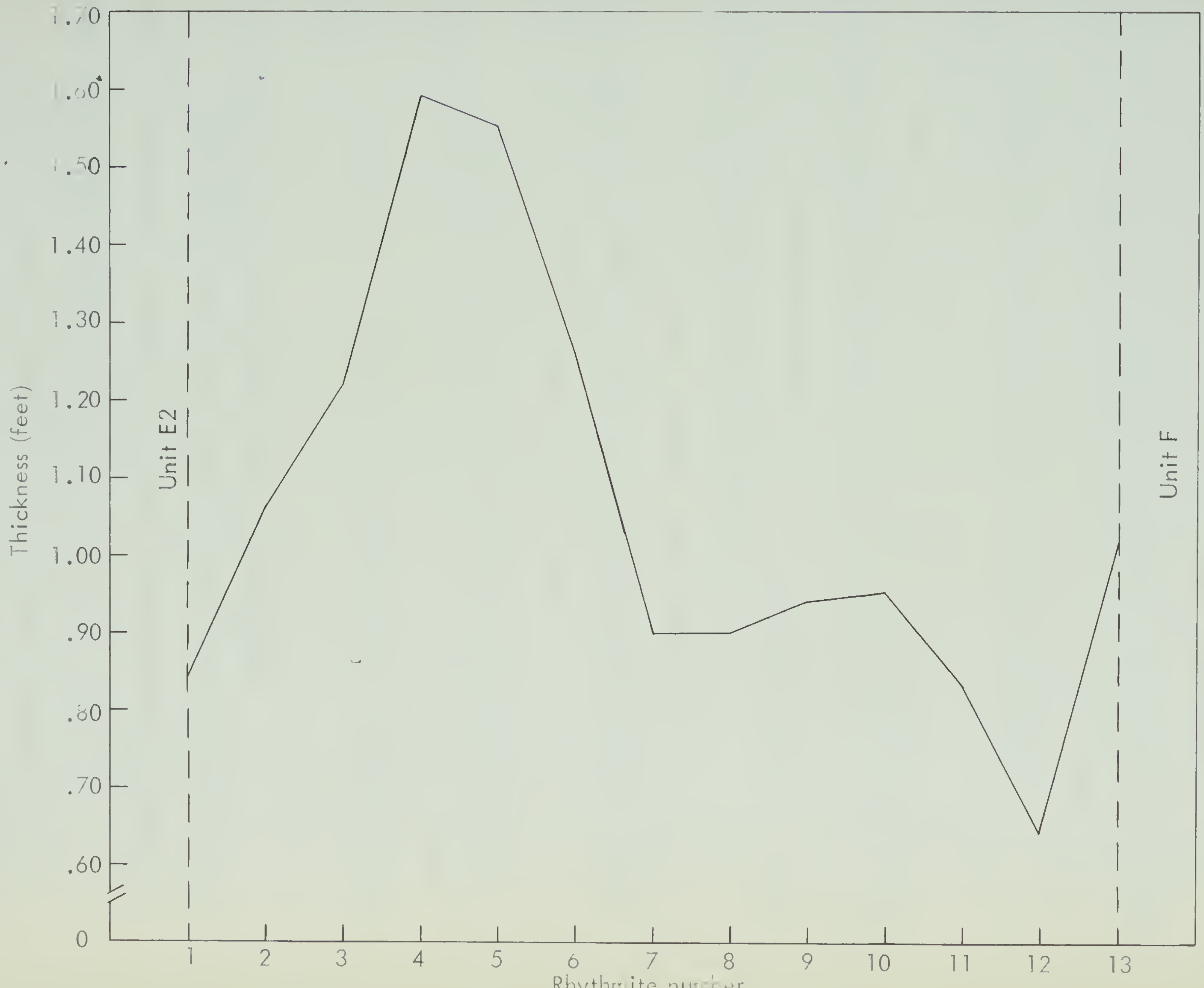


Figure 24. Variation in thickness of thirteen consecutive rhythmites in Unit E3

Unit E. Statistical parameters of grain size (Appendix D) show that the sediments of Unit E are very poorly sorted and strongly fine-skewed to fine-skewed.

The carbonate content of the -200 mesh part of the deposits in Unit E (Appendix F) ranged from 3.7 to 19.0 per cent with an average value for 21 samples of 9.5 per cent. The average calcite to dolomite ratio was 0.80. The majority of higher values were for samples taken from 0 to 30 feet below surface.

Unit F

Unit F is composed of wind-blown sands. At the outcrop section the sands are only a few feet thick (Plate 7b). Test holes situated on the top of dunes penetrated thicknesses of 30 feet of sand classified by the writer as aeolian deposits. The areal distribution of the aeolian sand is shown on figure 2.

Large sand dunes have moderately sorted, fine-skewed to near-symmetrical, coarser-grained sands than the smaller dunes which have poorly sorted to extremely poorly sorted, strongly fine-skewed, finer grained sands.

The carbonate content of the -200 mesh part of the deposits in Unit F (Appendix F) varied from near zero to about 20 per cent. The average carbonate content of 7 samples was 11.3 per cent. The average calcite to dolomite ratio was 1.49.

Summary of the Sequence and Nature of the Surficial Deposits

The sequence and nature of surficial deposits in the area are discussed on a basis of the geologic knowledge of this region of Alberta and the information obtained from the present study.

Medium to very fine sands of Unit A are the oldest sediments overlying bedrock in the area. The sands, known geologically as the Saskatchewan gravels

and sands, were deposited in deep, terraced valleys cut into the upper part of the bedrock. The main valleys contain 70 to 80 feet of sand and adjacent terraces or small tributaries up to 25 feet of sand. Deposition of the sands of Unit A ended with glaciation of the area. Till of Unit B was deposited by the glacier. The till is missing in some areas and ranges from a few feet up to 30 feet in thickness where it is present. Glacial meltwater eroded the till as the glacier retreated and gravels, sands, and silts of Unit C were laid down in a glaciofluvial environment. The deposits are widespread and range in thickness from a few feet to 40 feet. Unit C is overlain by till of Unit D which was deposited from the ice of a glacier that covered the area for a second time. This till is missing in some places, is thin over high areas on the bedrock surface, and up to 25 feet thick over the lows on the bedrock surface. The till of Unit D is overlain by sediments of Unit E which are predominantly very well-bedded glaciolacustrine sands, silts, and clays of glacial Lake Edmonton. Part of these sediments are characterized by the presence of till-like material and stones dropped from melting icebergs floating in the lake. The deposits are widespread in the area and range from 20 to 80 feet in thickness. The sediments become increasingly and progressively coarser from the base of the unit to the top. The upper part of the unit is sand where the total thickness of the unit is greatest. The sand in the upper part of Unit E, after modification by water, was reworked by wind into the sand dunes of Unit F. Sand deposits of large dunes exceed 30 feet in thickness. The dune field covers about two-thirds of the area. At the present time the dunes are stabilized by vegetation except for small blowouts.

HYDROGEOLOGY

Groundwater Chemistry

Introduction

The objective of the study of the groundwater chemistry was three-fold: 1) to determine the chemical types of groundwater in aquifers of the geologic units of the surficial deposits and the bedrock deposits, 2) to outline the occurrence of the chemical types of groundwater in the geologic units of the surficial deposits, and 3) to interpret the local groundwater flow systems in the area by studying the relationship of the groundwater chemistry to the geology and to the topography.

Groundwater samples were obtained for chemical analysis during the field programs carried out during the summers of 1965 and 1967. During 1965 water samples were taken from private water wells in the eastern half of the area situated north of the river. Test drilling in 1967 was conducted in such a manner that 2 to 5 samples of water, representative of aquifers at various depths below surface, were taken from each test hole. A total of 75 samples was collected and analyzed.

The specific electrical conductance for water samples from 102 wells located over the entire map-area was measured with a portable, battery-operated solu-bridge. Values in parts per million of pH, hardness, iron, and silica were determined in the field with "Hach Chemical Kits" for water samples collected during 1965 from Units E, F, and C. Chemical analyses of water samples in the laboratory were done by the former Provincial Analyst, C. E. Noble and the present Provincial Analyst, K. I. Strausz. Separate determinations of the Na^{+}, K^{+}, Ca^{++}, and Mg^{++} cations and the CO_3^{--} and HCO_3^{-} anions were made by the Provincial Analyst in addition to the standard chemical analysis that includes determinations of total

solids, ignition loss, hardness, sulfates, chlorides, alkalinity, nitrite nitrogen, nitrate nitrogen, iron, and fluoride. Appendix H contains tables of chemical analyses for groundwater in the surficial deposits and bedrock deposits.

Chemical Types of Groundwater in the Surficial Deposits

The chemical type of groundwater occurring in each unit of the surficial deposits was determined by plotting the results of each analysis on trilinear diagrams of the type proposed by Piper (1944). Groundwater in the surficial deposits has been classified into four chemical types, the limits of which are defined in figures 25, 26, and 27.

Type 1

Type 1 is a calcium-magnesium-bicarbonate water in quality. Type 1 is similar in quality to Type 2 but contains less than 30 per cent SO_4^{--}+Cl^- expressed as per cent of total anions. The grouping of Type 1 water samples from Unit C is very evident in the trilinear diagram of figure 26.

Type 2

Type 2 is a calcium-magnesium-bicarbonate-sulfate water. Type 2 water is similar in quality to Type 1 water but contains more than 30 per cent SO_4^{--}+Cl^- expressed as per cent of total anions. A number of wells with Type 2 water have nitrate concentrations greater than 10 per cent of total anions. This may indicate contamination by the leaching of decayed organic material. The presence of nitrates is often accompanied by the presence of chlorides. The NO_3^- as a per cent of total anions expressed as epm is included with the Cl^- in the anions triangle on the trilinear diagram (Fig. 25).

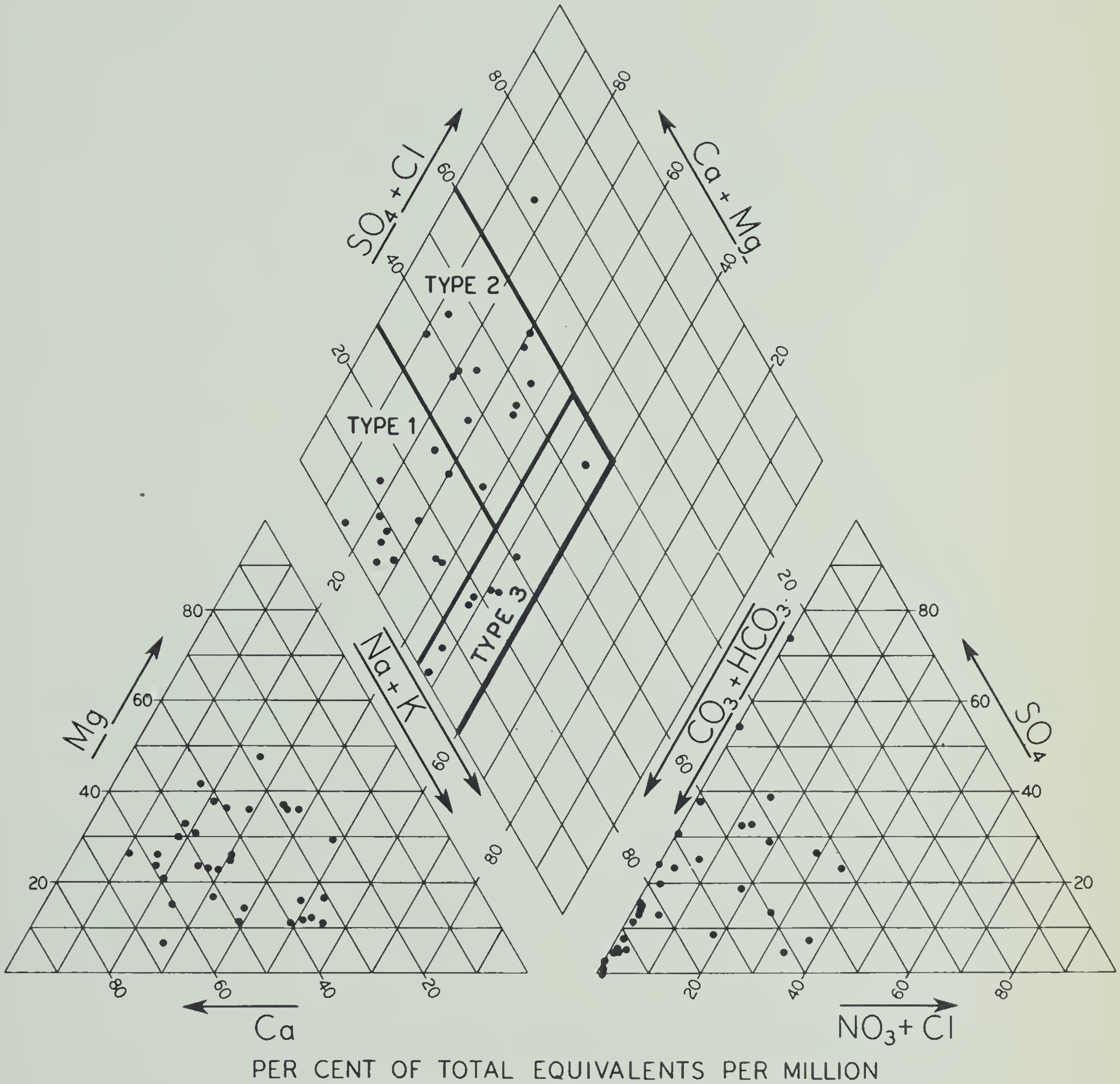


Figure 25. Trilinear diagram showing the three main chemical types of groundwater in Units E and F, in epm

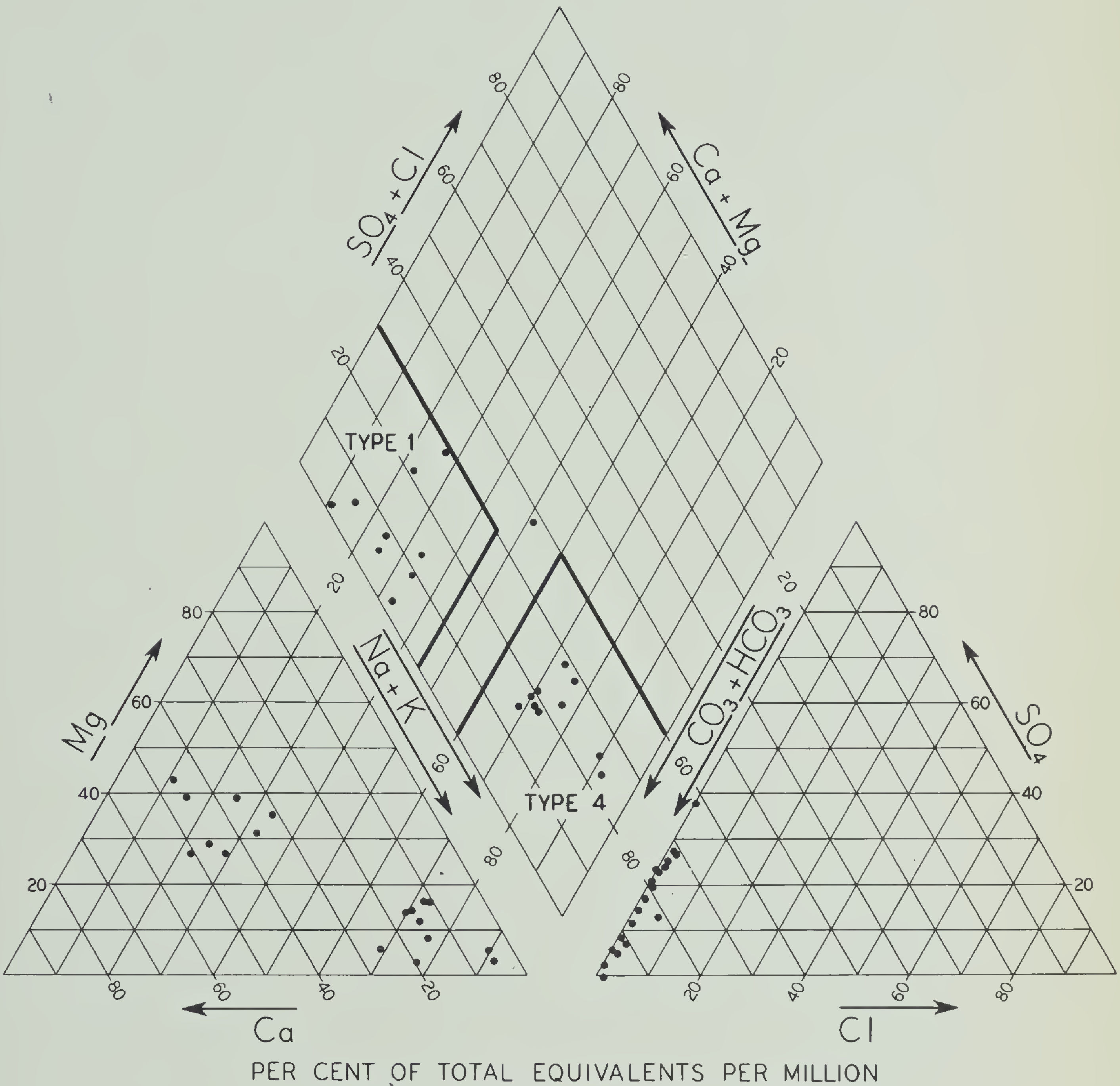


Figure 26. Trilinear diagram showing the chemical types of groundwater in Unit C, in epm.

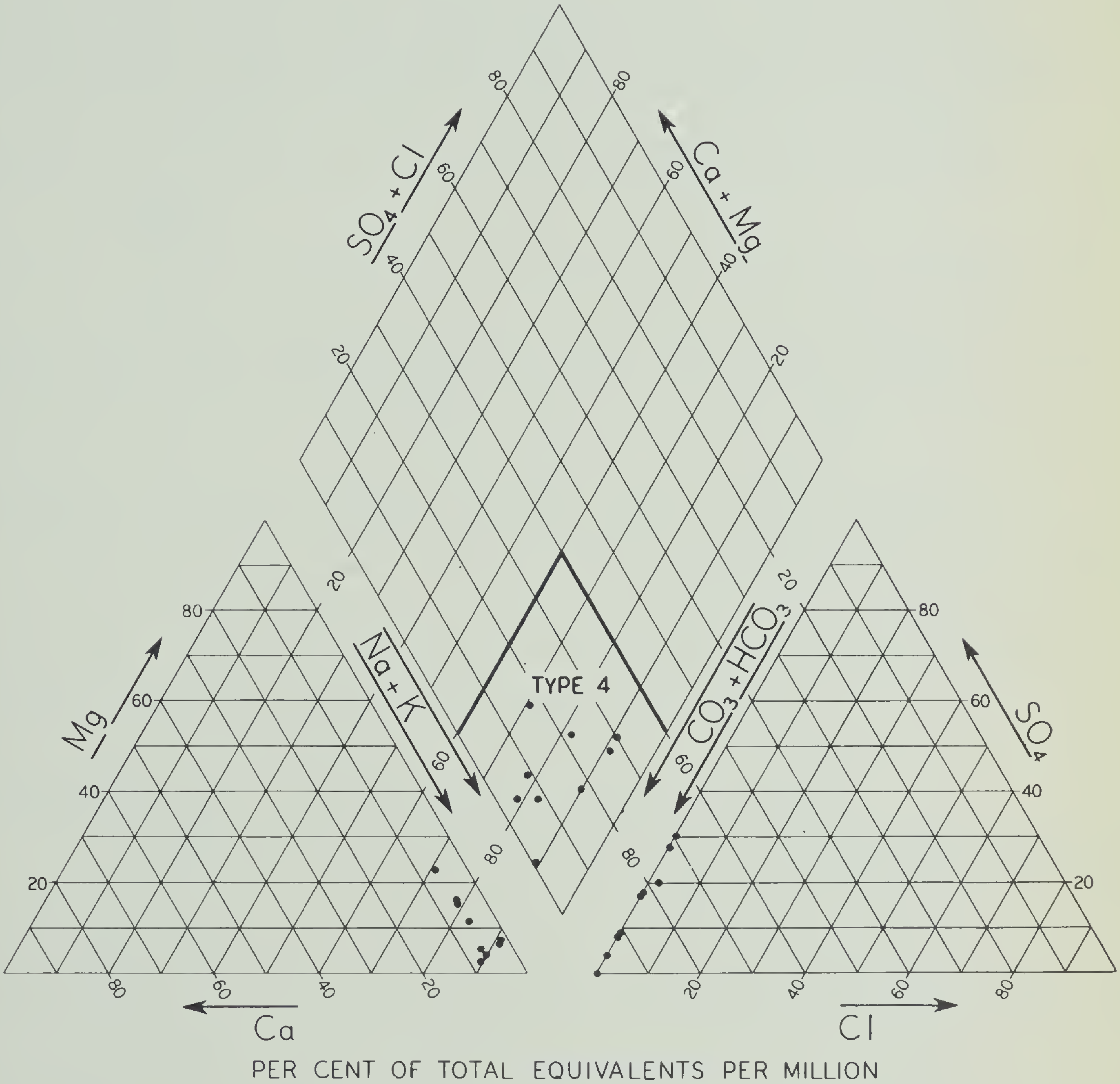


Figure 27. Trilinear diagram showing the chemical type of groundwater in Unit A, in sp

Type 3

Type 3 is a sodium-potassium-calcium-magnesium-bicarbonate water in quality, containing roughly equal amounts in per cent of total equivalents per million (epm) of the cations. Type 3 is somewhat separate from Types 1 and 2, the cation grouping in the trilinear diagram (Fig. 25) being distinct. The water contains greater than 45 to 60 per cent Na^{+}+K^{+} and more than 40 per cent CO_3^{--}+HCO_3^{-} expressed as equivalents per million of total cations and anions, respectively.

Type 4

Type 4 is a sodium-potassium-bicarbonate water. The concentration of the Na^{+}+K^{+} cations in epm increases with depth in Unit C and are highest in Unit A. Corresponding to this, the Ca^{++}+Mg^{++} cations decrease with depth. The CO_3^{--} + HCO_3^{-} anions increase with depth, but reach a depth where the concentration in epm remains relatively constant. From this point downward the SO_4^{--} anion increases moderately. These features are apparent in figures 26 and 27 and are illustrated diagrammatically in figure 28 by Stiff diagrams (Stiff, 1951).

Other Quality Factors for Groundwater in Units E, F, C, and A

Dissolved iron content for groundwaters in the surficial deposits ranges from 0.3 to 3.0 parts per million (ppm) in Units E, F, and C. Concentrations greater than 3.0 ppm occur at certain localities in Units E and F and more commonly in Unit C. Dissolved iron content in groundwater in Unit A ranged from 2 to 10 ppm.

Silica content of groundwater in Units E and F ranges from 2 to 7.5 ppm. A few samples contained concentrations of silica greater than 10 ppm and two very high values of silica of 100 and 125 ppm were determined. The greatest values were for water samples from wells closest to the river valley. The silica content in groundwater of Unit C was over 100 ppm for seven out of 11 samples analyzed. The re-

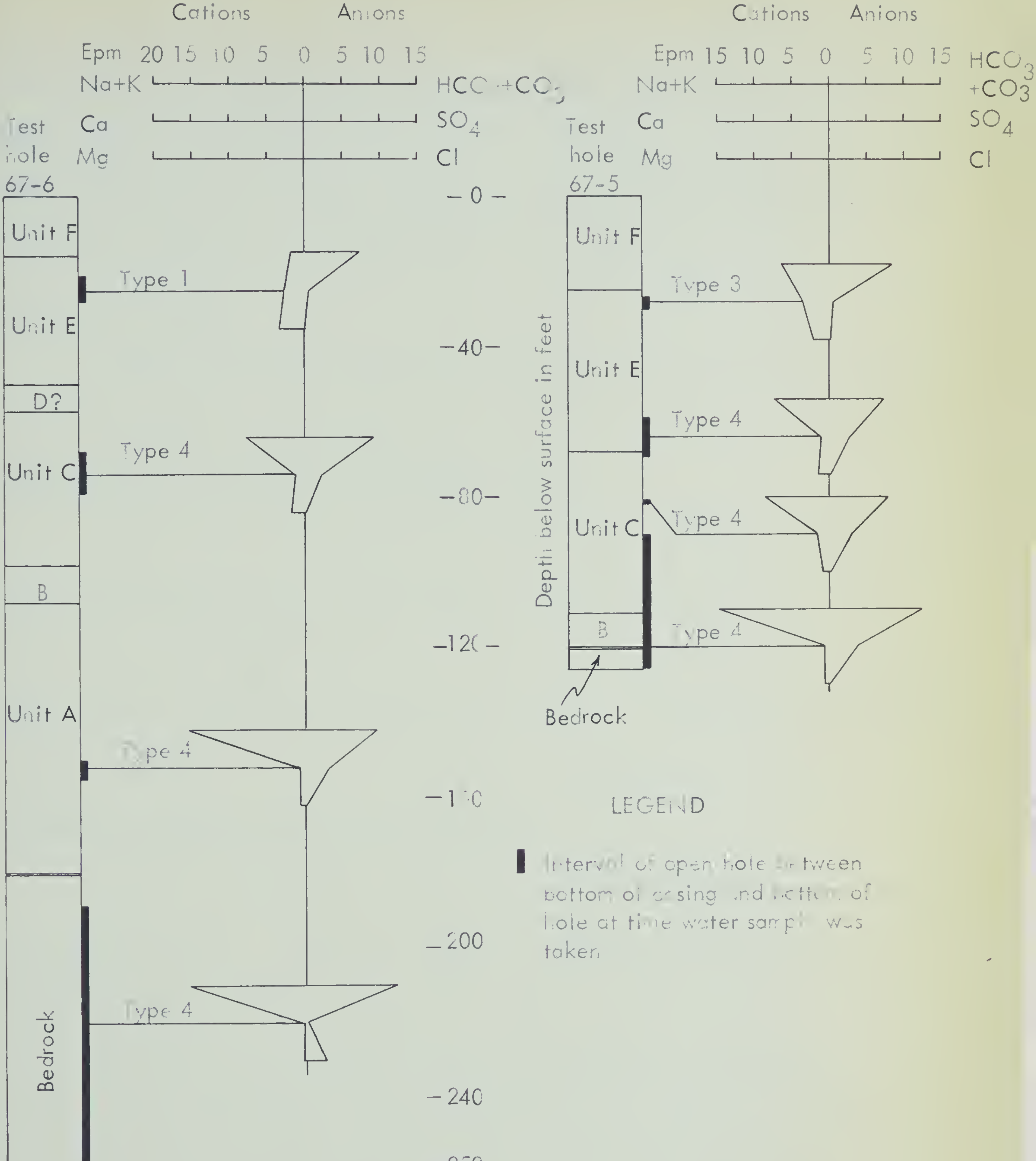


Figure 28. Change in water quality in surficial and bedrock deposits with increasing depth of aquifer below surface

maining four samples contained 5 to 10 ppm silica concentration.

Hardness in groundwater of Units E and F ranged from 200 to 400 ppm. Water with hardness values of this range is considered very hard water. Water in Unit C has hardness values predominantly in the range from 100 to 250 ppm and is considered moderately hard to hard water. Hardness values for a number of samples were as high as 300 to 400 ppm. Hardness in groundwater of Unit A ranged from 50 to 100 ppm. This is a moderately soft water.

Water in Units E, F, and C has pH values ranging from 6.5 to 7.4, whereas water in Unit A has pH values ranging from 8.4 to 8.7.

Chemical Type of Groundwater in the Bedrock Deposits

Type 4 is the chemical type of water occurring in the bedrock deposits. The water in the bedrock generally contains higher concentrations of $Na^{+}+K^{+}$ in epm than water in the surficial deposits (Fig. 29). The majority of waters sampled had a chloride content less than 15 per cent of total anions expressed as epm. Wells deeper than 300 feet yield water with chlorides greater than 15 per cent of total anions in epm.

Suitability of Groundwater for Human Consumption

The four types of water in the surficial and bedrock deposits are all suitable for human consumption. Dissolved iron may be an undesirable element in water in the surficial deposits. Shallow wells in Units E and F are subject to contamination and the water from these wells should be analyzed periodically for the presence of nitrates. Deep wells in Unit C, Unit A, and the bedrock deposits occasionally may be found to contain amounts of soda in excess of the limit of 50 grains per gallon recommended by the Alberta Department of Public Health for water for human consumption. It may be desirable to treat the water for hardness and for

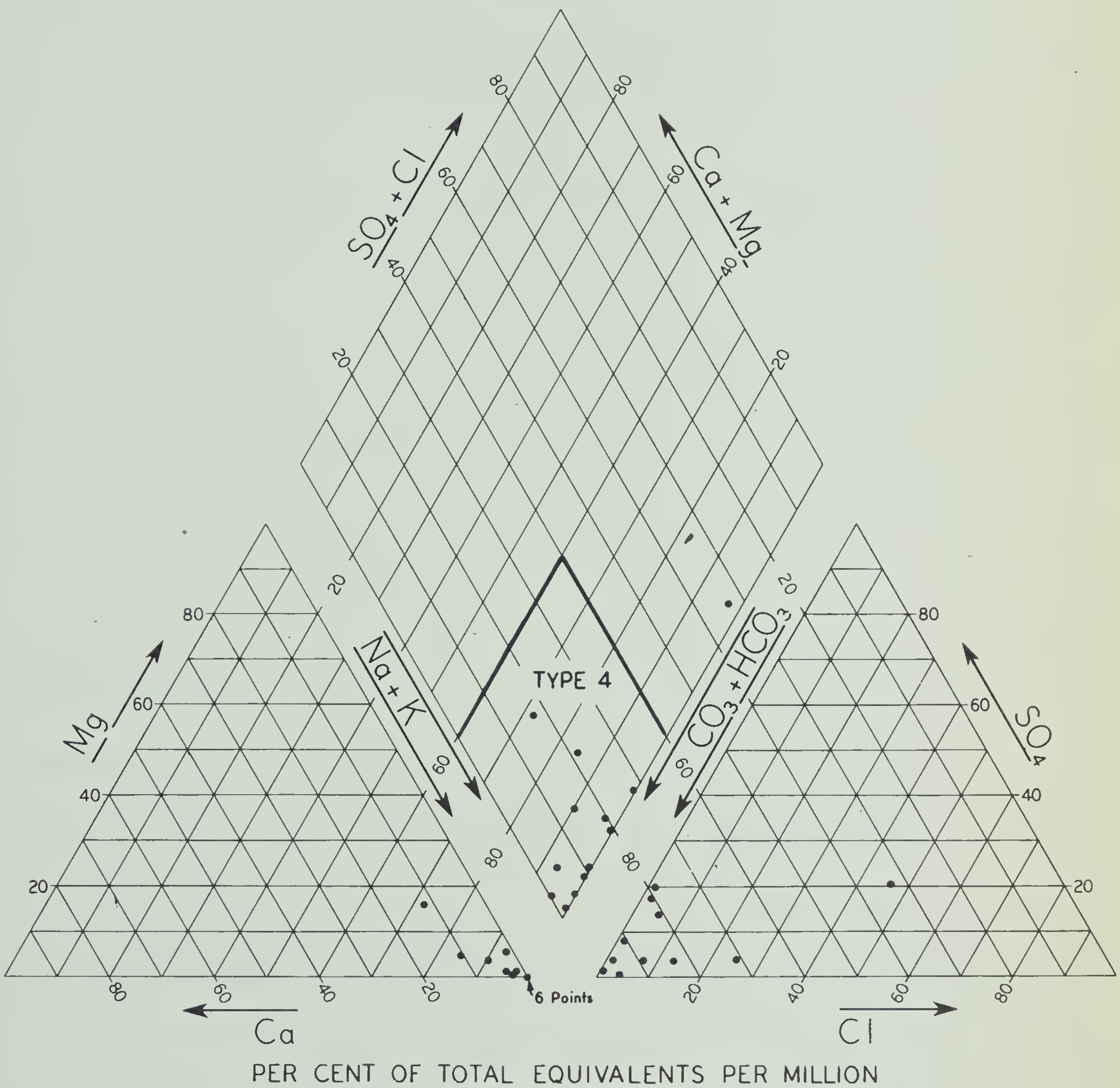


Figure 29. Trilinear diagram showing the chemical type of groundwater in the bedrock deposits, in epm

the removal of iron, depending on the desired use of the water.

Occurrence of the Chemical Types of Groundwater in the Units of the Surficial Deposits

The occurrence of chemical types of groundwater in Units E and F is shown in figure 30. Units E and F are considered as one aquifer because wells completed in these deposits receive groundwater from both units or it is difficult to determine which of the two units is yielding water to the well. The majority of water samples analyzed from Units E and F are either Type 1 or Type 2. In Units E and F, Type 1 occurs along with Type 2 over most of the area sampled except for a narrow zone paralleling the river. In this zone Type 3 water occurs. Three occurrences of Type 3 water fall in the area of occurrence of Types 1 and 2 water. The approximate boundary in figure 30 might be considered as being subjective because the area north of the boundary could be divided into a number of smaller areas in which Type 1, 2, or 3 water occurs. Type 3 water is considered distinctive from Types 1 and 2 because of its higher soda content. For this reason the approximate boundary separating areas of predominantly Type 3 water from areas of predominantly Types 1 and 2 water is considered the most important one. In Unit C the occurrence of Type 1 water is most frequent in a narrow zone along the river (Fig. 31). Types 2 and 3 do not occur in Unit C. Type 4 groundwater is found north of the zone of Type 1 water. The approximate boundary in figure 31 can be drawn objectively where the density and distribution of control points is adequate. Type 4 water is the only chemical type of groundwater found to occur in aquifers of Unit A. The approximate boundaries of the buried valley type aquifer which contains groundwater of Type 4 are shown in figure 4. The locations of other buried valleys which could contain deposits of Unit A are shown in figure 3.

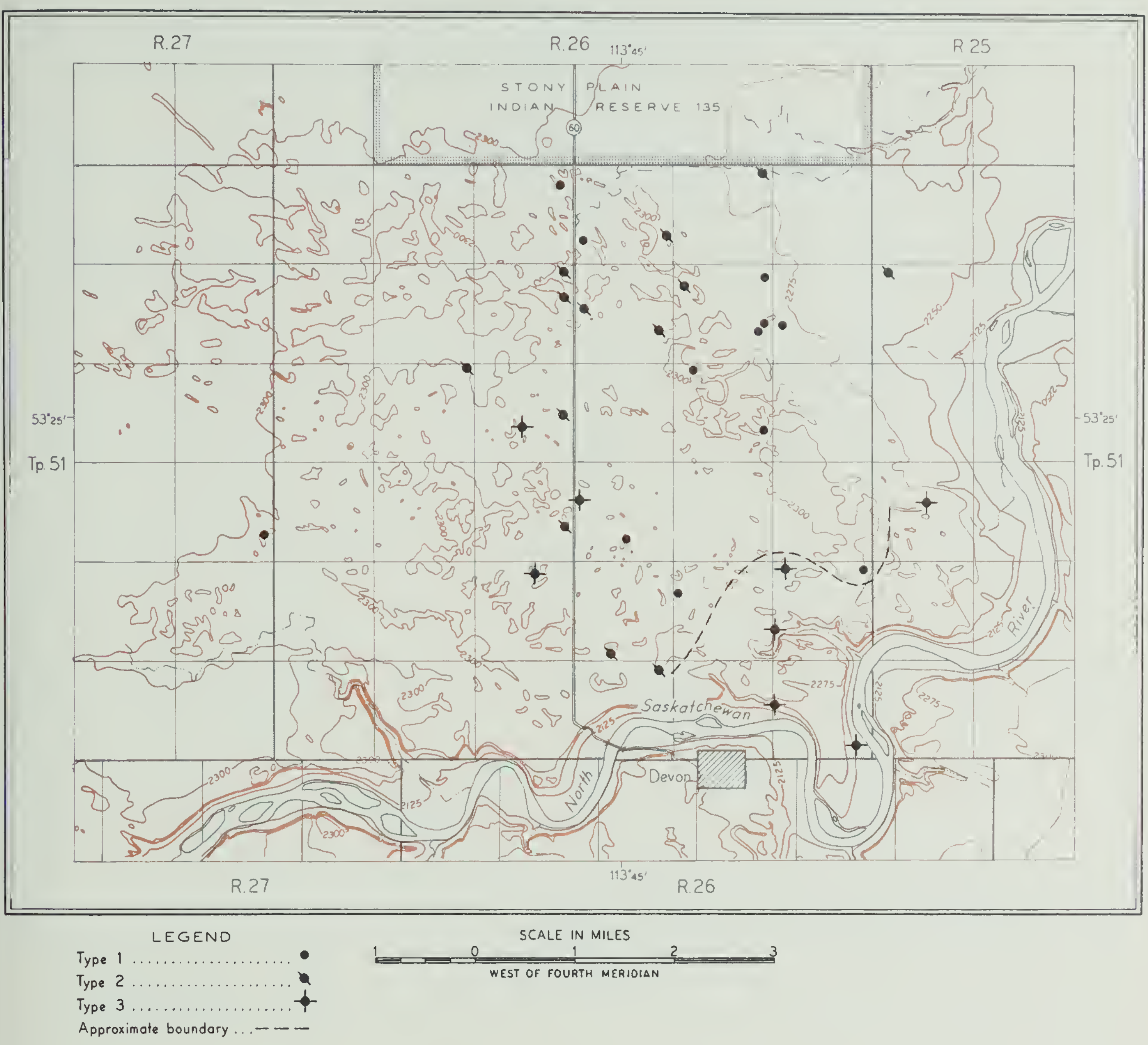


Figure 30. Map showing the occurrence of chemical types of groundwater in Units E and F

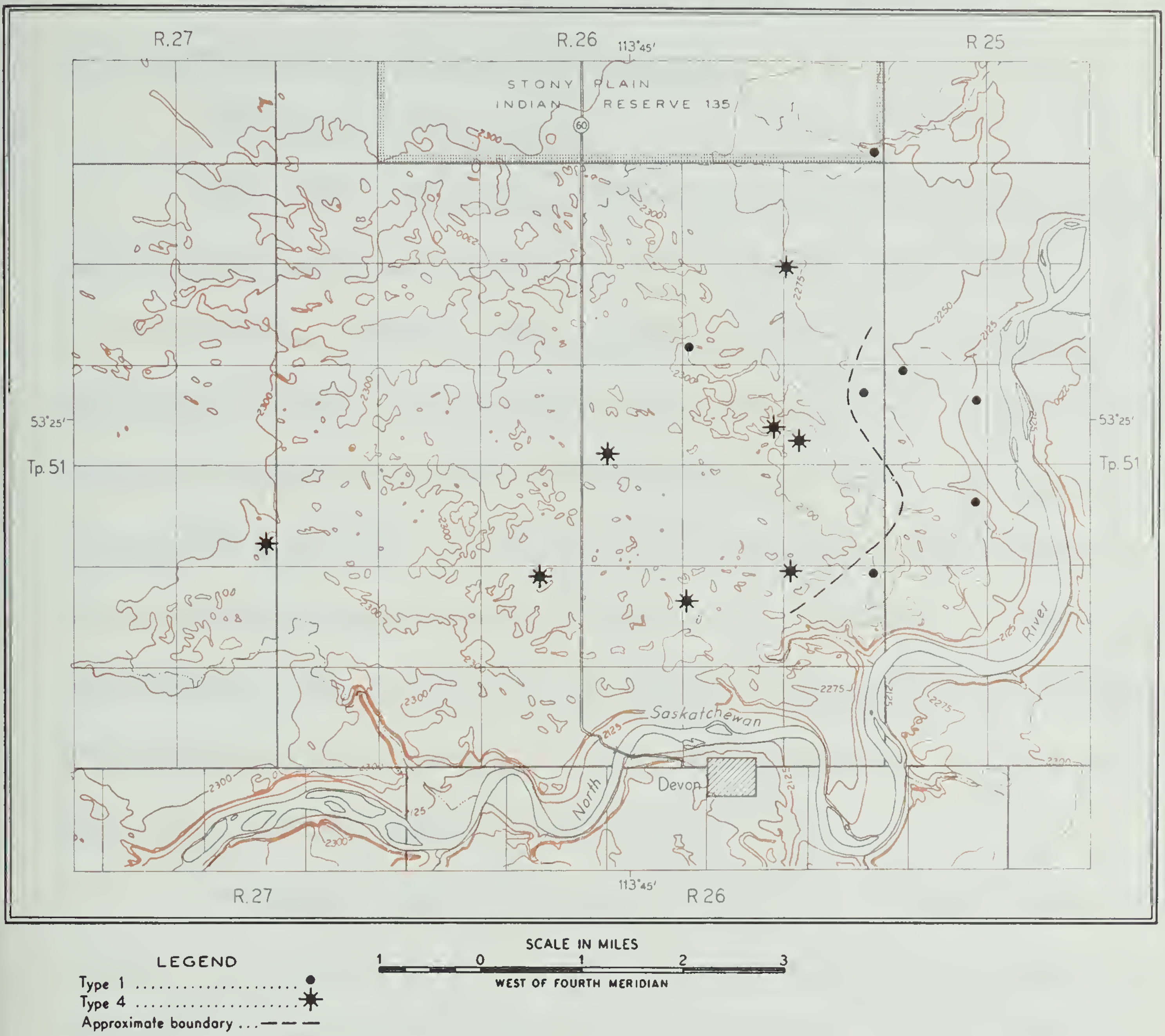


Figure 31. Map showing the occurrence of chemical types of groundwater in Unit C

Interpretation of Groundwater Flow Systems in the Area Based on Groundwater Chemistry, Geology and Topography

Hydrochemical flow systems

Tóth (1966a, 1966b) showed that a chemical quality study of groundwater can supply information about the direction and extent of groundwater flow systems in central Alberta. Le Breton (1966) and Tokarsky (1967) related the groundwater quality to the geology and flow systems in other parts of Alberta. Rozkowski (1967) carried out detailed investigations of hydrochemical patterns in hummocky moraine in southern Saskatchewan. He concluded that the development of hydrochemical patterns was determined by climate, lithological composition of the glacial deposits, and conditions of groundwater flow. Tóth (1966a), Meyboom (1966), and Rozkowski (1967) all emphasize the importance of the contact time between water and rock in determining the degree of mineralization of groundwater.

Investigators studying flow systems in different environments have usually arrived at one common conclusion — recharge areas are coincident with topographically high areas and discharge areas with topographically low areas, regardless of the scale of the flow system. However, Tóth (1963) found it necessary to stress the sense in which recharge and discharge is used in hydrochemical studies. Tóth defined recharge and discharge as "the processes by which water is added or removed from any part of the zone of saturation". He subdivided the processes of recharge and discharge into two main groups as quoted below:

"1) Processes in which water is exchanged between the saturated zone and either the atmosphere or the zone of aeration.

2) The process in which water is exchanged between different parts of

the saturated zone. This process is termed herein 'the saturated flow of groundwater'." The writer uses the definition in 2) in subsequent discussion.

The important cations in the groundwater of the surficial deposits in the area of study are Ca^{++}, Mg^{++}, Na^{+}, and K^{+}; the important anions: HCO_3^-, CO_3^{--}, and SO_4^{--}.

Based on the hydrochemical investigations previously mentioned and considering the important ions in groundwater of the study area, the following characteristics apply to recharge and discharge areas of short flow systems:

Recharge Area	Discharge Area
(1) Low total solids, in ppm	(1) Slight increase in total solids, in ppm
(2) High calcium and magnesium, in per cent of total cations	(2) Decreasing calcium and magnesium, in per cent of total cations
(3) High calcium:magnesium ratio	(3) Lower calcium:magnesium ratio
(4) Lower sodium plus potassium, in per cent of total cations	(4) Relatively rapid increase in sodium, in per cent of total cations
(5) High carbonate and bicarbonate, in per cent of total anions	(5) Less pronounced bicarbonate, in per cent of total anions
(6) Little sulfate, in per cent of total anions	(6) Higher sulfate, in per cent of total anions

Sources of chemical constituents in groundwater

The following discussion is taken from Davis and DeWiest (1966) and Hem (1959). It is presented here for background information to supplement subsequent discussion of the concentration and areal distribution of the major anions and cations present in groundwater of the study area.

Sodium compounds are readily soluble and when leached from the rocks tend to stay in solution. Sodium-bearing waters may under some circumstances participate in base-exchange reactions whereby sodium replaces other cations in clay minerals or other materials. Many clay minerals, particularly montmorillonite, have a capacity for base exchange. Normally, calcium and magnesium ions from solution replace adsorbed sodium on the exchange material.

Potassium is slightly less abundant than sodium in the earth's rocks but is easily recombined with the products of weathering, particularly the clay minerals of hydrolyzate sediments. Potassium minerals are more resistant to decomposition by weathering than are sodium minerals.

Calcite and dolomite are the most important common sources of calcium and magnesium. The solubility of calcium carbonate and magnesium carbonate is controlled by the presence of carbon dioxide. Calcium and magnesium cations in solution will replace sodium cations adsorbed on clay minerals. Magnesium is usually less abundant than calcium because of the slow dissolution of dolomite and the greater abundance of calcium in the earth's crust.

The most important sources of sulfate in groundwater are gypsum and anhydrite. Both minerals are highly soluble. Sulfate-reducing bacteria derive energy from the oxidation of organic compounds and in the process obtain oxygen from the sulfate ions in subsurface water. The resulting reduction of sulfate ions produces hydrogen sulfide as a by-product.

Most bicarbonate and carbonate ions in groundwater are derived from the CO_2 in the atmosphere, CO_2 in the soil, and the solution of carbonate rocks. In groundwater with pH values between 4.5 and 8.2, most of the carbonate ions add

hydrogen to become bicarbonate ions.

Silica is one of the most abundant elements of the earth's crust but silica compounds have low solubilities. Subsurface waters saturated with amorphous silica in temperate regions should contain from 90 to 110 ppm of silica.

Iron exists in abundance in many minerals of the earth's crust. The weathering of these minerals releases large quantities of iron which usually are converted to the relatively insoluble and stable iron oxides. Iron is usually considered to be in the ferrous form in subsurface waters with pH values between 6.0 to 8.0. On exposure to the atmosphere the ferrous iron is oxidized and precipitates as ferric hydroxide.

Sources of some major cations and anions in the surficial deposits of the study area

X-ray diffraction studies of the clay fraction (-2 microns) of surficial deposits from test holes 67-1, 67-2, and 67-3 showed that montmorillonite was the most abundant clay mineral present, with smaller amounts of kaolinite, some illite, and probably minor amounts of chlorite. The clays of the montmorillonite group are probably the main source of sodium for base exchange reactions since they are widespread in the area and have a high exchange capacity.

Heavy calcification up to 1/4 inch in diameter fills the spaces formerly occupied by roots which have decayed. The calcification was observed to extend to depths ranging from 4 to 12 feet below surface in bulk samples recovered from test drilling. Average values of carbonate in the -200 mesh part of Units E and F were 9.5 and 11.3 per cent, respectively. Units B and D had lower carbonate contents with average contents of 3.8 and 5.1 per cent, respectively. The tills of

Units B and D contain about twice as much dolomite as calcite, Unit E has close to equal amounts, and Unit F has calcite concentrations about 1 1/2 times that of dolomite present. The higher values of carbonate content were measured in samples taken from 0 to 30 feet below surface.

Pyrite and gypsum were identified in samples of the surficial deposits. Gypsum was found to be crystallized along joint planes, particularly those in Unit D. Gypsum is an important source of sulfate and sulfate is produced through the oxidation of pyrite.

Nitrate and chloride concentrations in shallow wells are probably the result of leaching by percolating water of barnyard manure or other organic wastes.

The areal distribution and concentration of chemical constituents of groundwater in Units E and F

Few reliable measurements of the change in the natural potential of groundwater with depth are available in the study area. It would thus be difficult to establish a three-dimensional picture of fluid-potential distribution in the area from which flow systems present could be delineated.

The interpretation of flow systems in the area of study is based primarily on an analysis of water samples from Units E and F because the majority of water wells from which water samples were obtained were completed in the deposits of these units. The patterns of areal distribution of chemical constituents have been drawn as objectively as possible but a subjective approach was necessary for all patterns except that for the areal distribution of sodium and potassium ions (Fig. 32) which is shown by contours of percentage of total cations. The remaining patterns show approximate boundaries between various ranges of concentration of

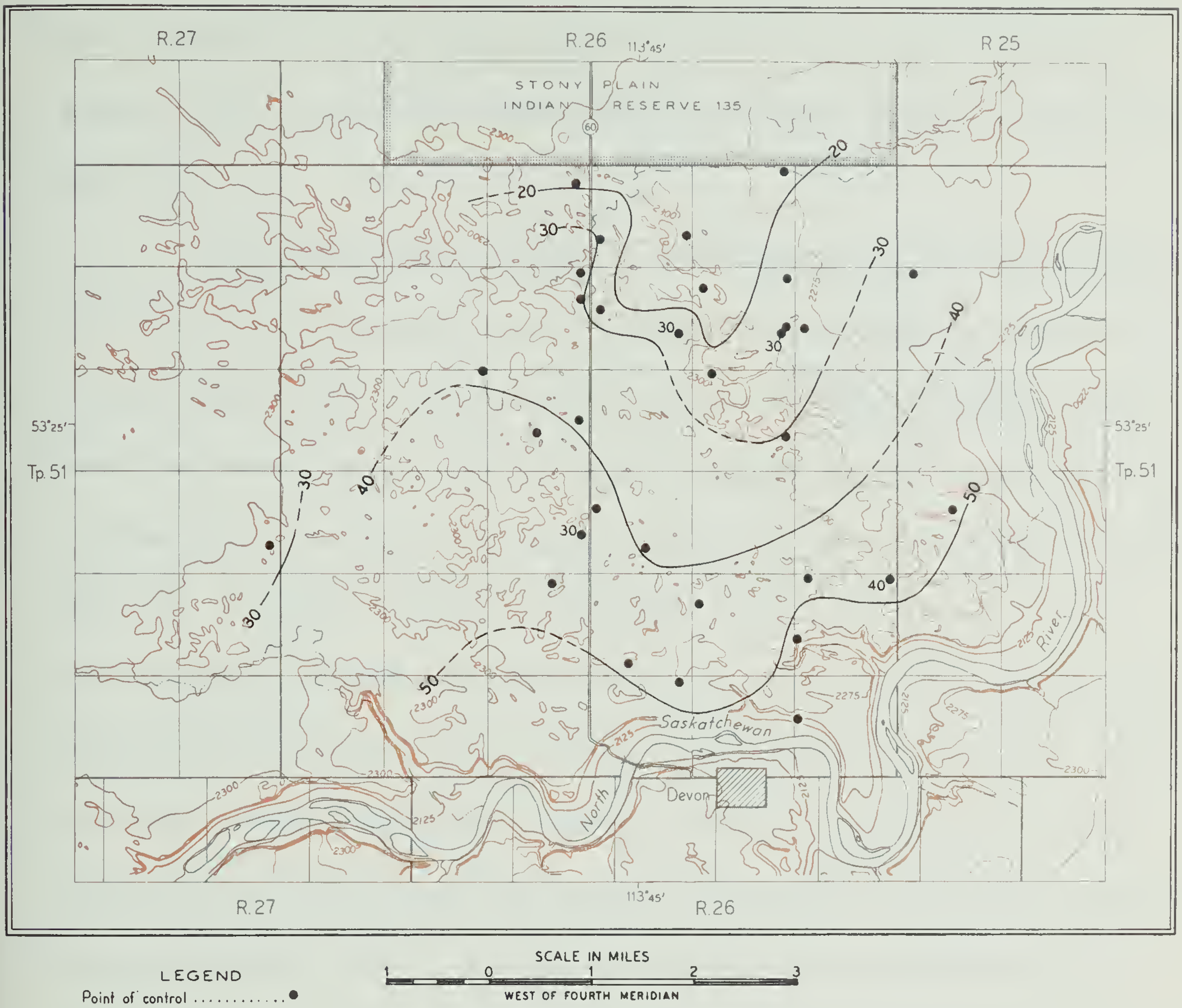


Figure 32. Map showing areal distribution of sodium and potassium ions, in percentage of total cations, for groundwater in Units E and F

chemical constituents. The positions of the boundaries have been determined on a basis of theoretical considerations and the range of values that give the clearest pattern of the concentration of each chemical constituent has been decided by trial and error.

Total solids in ppm are higher in an area about one mile wide which parallels the North Saskatchewan River (Fig. 33). The areal distribution of total solids in ppm for groundwater in all the surficial deposits and bedrock deposits, as calculated from measurements of specific electrical conductance, shows a central northwest-trending zone of low total solids which is surrounded by an area of higher total solids (Fig. 34). Figure 34 also indicates higher total solids in an area near the river. Calcium:magnesium ratios are higher in the northern part of the area and decrease toward the river with the exception of high values near the river (Fig. 35). The concentration of sodium and potassium ions in percentage of total cations increases rapidly from low values in the north to values of about 50 per cent in the vicinity of the river (Fig. 32). There is a noticeable bend in the iso-percentile lines to the northwest in the map-area. The areal distribution of carbonate and bicarbonate in percentage of total anions is relatively uniform over the area with the exception of a central area of high values (Fig. 36).

Interpretation of hydrochemical flow systems in the area

The salient features of the areal distribution of the total solids in Units E and F indicate that the dune field as a whole is a recharge area with a discharge area occupying a narrow zone paralleling the North Saskatchewan River. Figure 34 also reflects the influence of numerous smaller, shallower flow systems

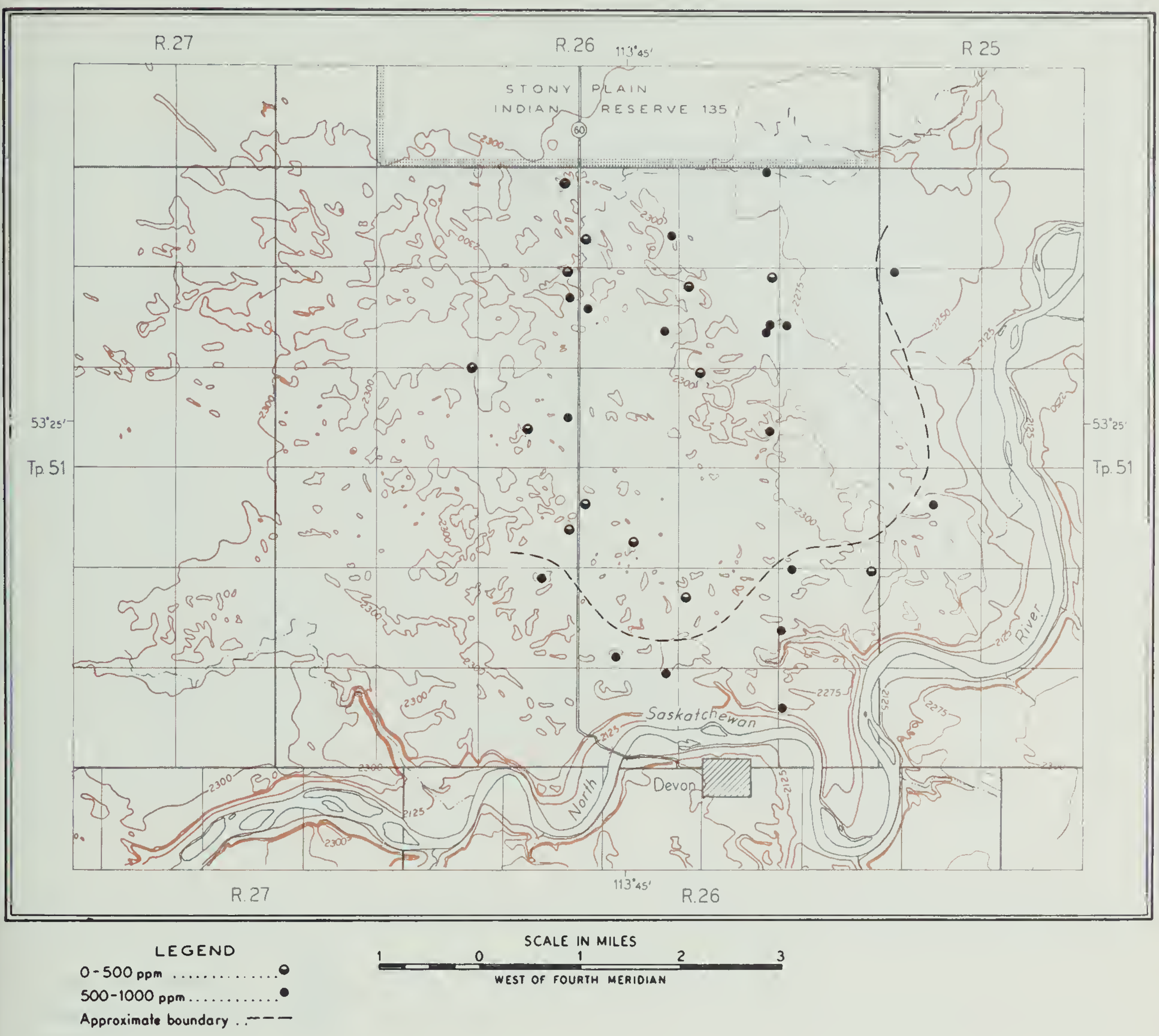


Figure 33. Map showing areal distribution of total solids in groundwater in Units E and F

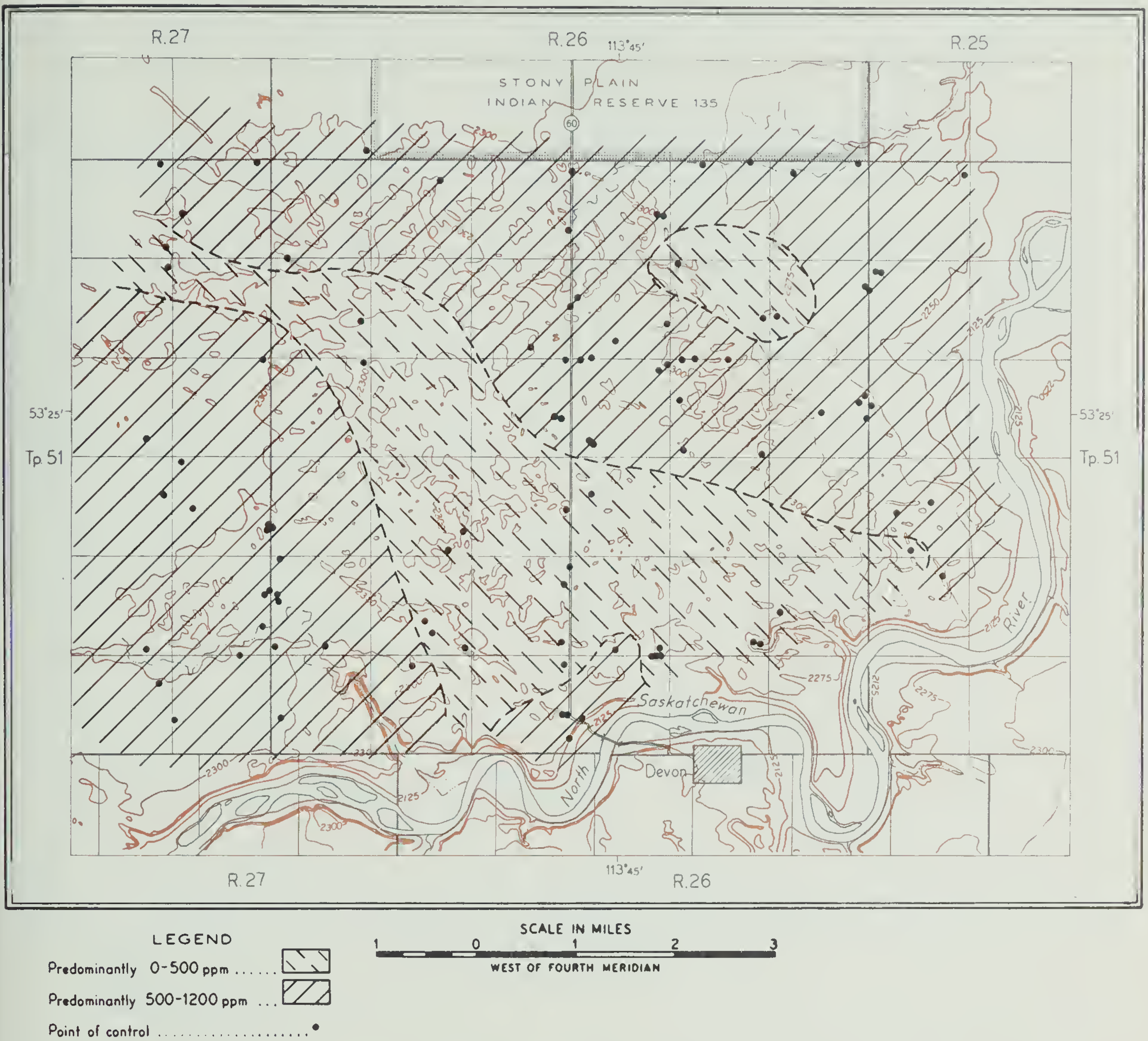


Figure 34. Map showing areal distribution of total solids for groundwater in the surficial and bedrock deposits (calculated from specific electrical conductance measurements)

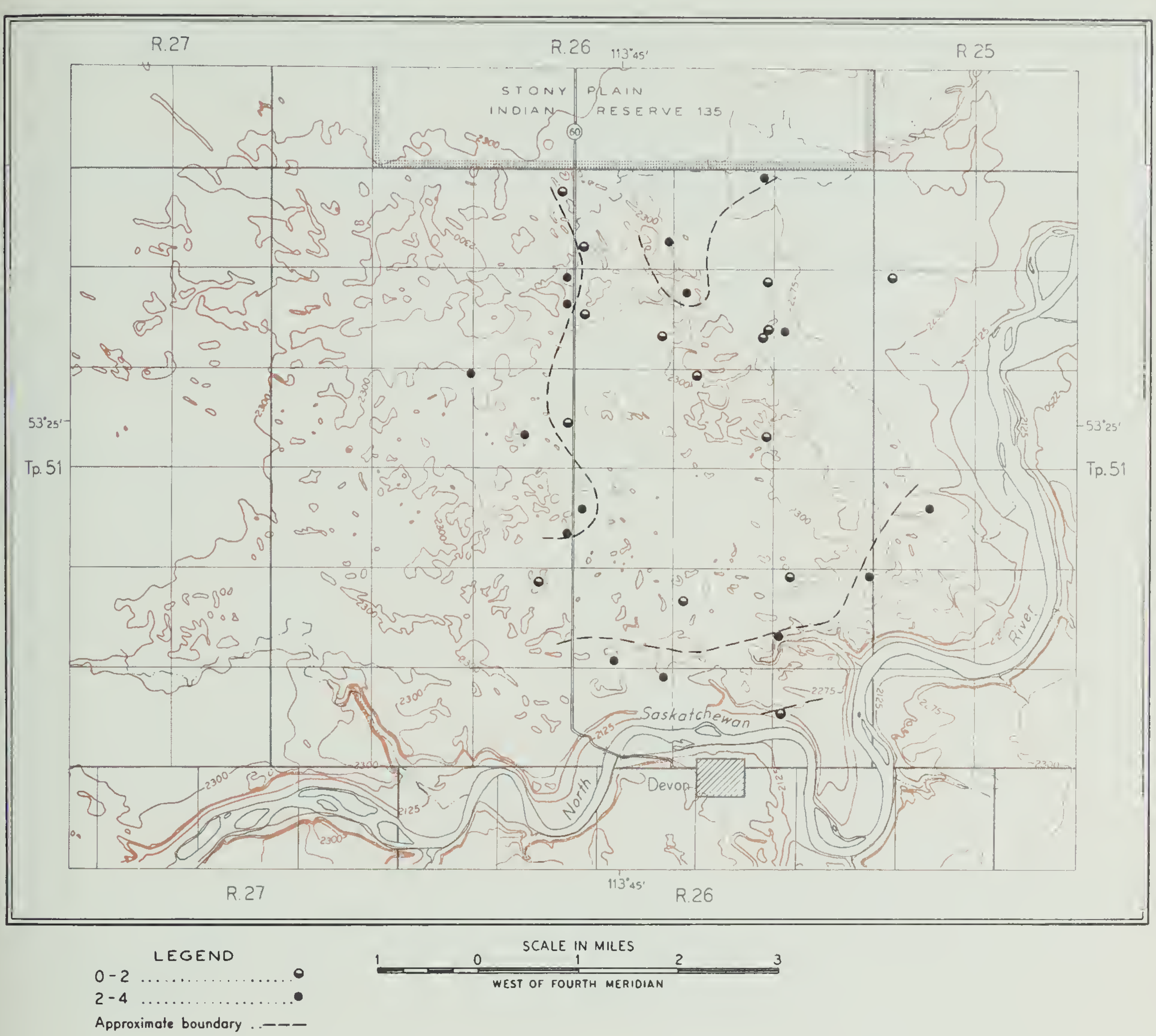


Figure 35. Map showing areal variation in the calcium:magnesium ratio for groundwater in Units E and F

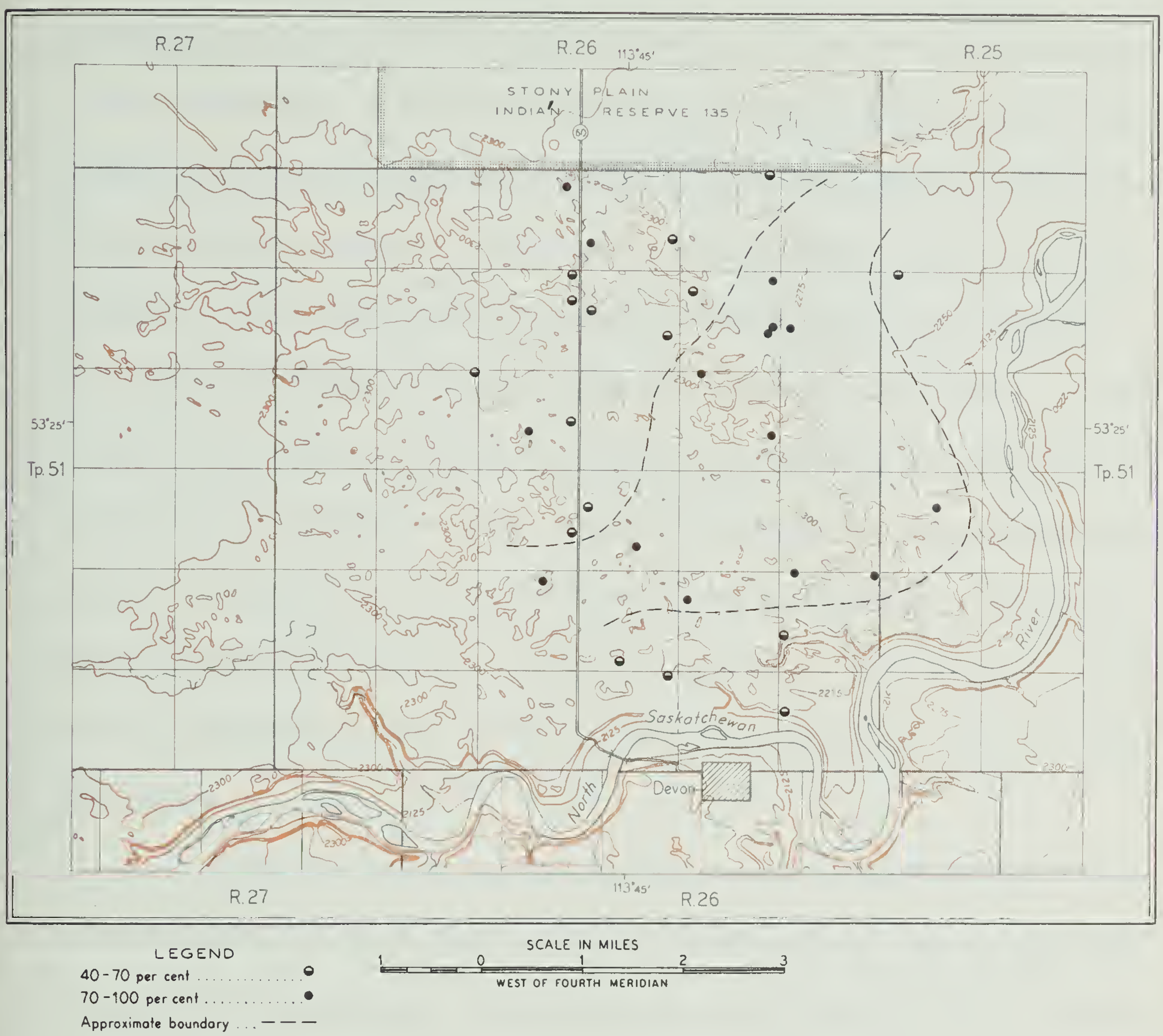


Figure 36. Map showing areal distribution of carbonate and bicarbonate ions in percentage of total anions, for groundwater in Units E and F

with dunes as recharge areas characterized by low total solids and interdune lows as discharge areas characterized by high total solids. The low concentration values of sodium and potassium in Units E and F are indicative of short flow systems. Tóth (1966a) found that the sodium concentration increases very rapidly in young waters. This phenomenon is apparent in the dune area and is probably a result of base exchange due to the high concentration of clay minerals in the surficial deposits. The occurrence of high concentration values of carbonate and bicarbonate in Units E and F in the central part of the area cannot be explained by the writer. As a whole, the areal distribution of the carbonate and bicarbonate anions is considered a measure of the influence of the small flow systems of the individual dunes and their respective interdune lows. The zone along the river is the only one in which values of carbonate and bicarbonate were found to be less than 70 per cent of the total anions.

In the area paralleling the river the presence in Unit C of Type 1 water characterized by low total solids and high calcium:magnesium ratios in Units E and F suggest a zone of recharge. This recharge zone must interfinger with the discharge area of the dune field. The recharge area paralleling the river means downward flow of water in the zone of saturation. This suggests that the North Saskatchewan River valley influences the direction of groundwater flow in the area adjacent to the top of the river valley wall.

The presence of Type 4 water in Unit C in the northwest part of the study area, in Unit A, and in the bedrock aquifers, suggests that the water in these units belongs to a long or regional flow system.

Groundwater Availability of Aquifers in the Surficial Deposits

Aquifers in Units E and F

In the early settlement of the area water was obtained entirely from wells bored or dug into the aeolian sand (Unit F) or upper sandy deposits of Unit E. A number of homes in the area still depend on this aquifer for a water supply. The groundwater levels (water table) in this aquifer range from about 4 feet below surface in topographically low areas to 20 feet below surface on the top of large dunes. Generally, the aquifer materials have low permeabilities except for local areas where the deposits are sandier. The amount of water the aquifer will yield to a well depends largely on the type of well but long-term yields will probably not be greater than 5 imperial gallons per minute. The maximum depth of wells is usually at the depth where sandy deposits overlie the silty clay deposits of Unit E. This is usually less than 40 feet over most of the area.

Aquifers in Unit C

Unit C contains layers of clean sands which generally have higher permeabilities than aquifer material in Units E and F. In the last few years a number of private water supplies have been developed in these sands. The top of the deposits in Unit C is found below 50 feet and the bottom less than 150 feet below surface in the area.

Water levels measured after 12 hours of recovery in test holes in Unit C are listed in the table below.

Test Hole No.	Depth of test hole below surface (feet)	Depth of water level below surface (feet)
67-2	90	46.78
67-4	84	39.73
67-5	82	46.23

A second twelve-hour recovery measurement at test hole 67-5 showed a water level of 20.95 feet below surface for a test hole depth of 126 feet. The test hole was in bedrock deposits at this depth. The two measurements indicate increasing natural potential with depth at the location of test hole 67-5.

Wells of good design, which usually requires the installation of a suitable well screen or a well screen and "gravel" pack, should produce 5 to 15 gallons per minute from the best water-bearing sands in Unit C. The main problem is the positioning of the screen in a well because the better sand aquifers are thin and accurate knowledge of the top and bottom of the subsurface sand is necessary for successful water well construction. Electric logging of drill holes prior to well completion is recommended, particularly for rotary drilled holes. Little difficulty will be encountered in determing the presence and position of good water-bearing sands with an electric log and lithologic infoımation.

Aquifers in Unit A

Unit A is potentially the most promising aquifer in the area. This aquifer was evaluated by a pumping test at the site of test hole 65-3. The analysis of the pumping test data is presented separately in this thesis. Measured water levels in Unit A after long periods of no pumping are listed in the table below.

Test Hole No.	Depth of the test hole below surface (feet)	Depth of water level below surface (feet)	Elevation of water level (feet)
65-3	180	52	2,220
EP4	152	73	2,228
M2	163	68	2,232
67-6	155	44	2,256

The water-level measurements show a drop in natural fluid potential in the aquifer from southwest to northeast along the course of the buried valley. The bedrock topography to the northeast of the study area (Carlson, 1967, Fig. 2c) shows that the buried valley is intersected by a large curve of the North Saskatchewan River in Secs. 9 and 16, Tp. 52, R. 25, W. 4th Mer. This meander is locally known as the "Big Bend." At this location numerous contact springs drain Unit A which overlies bedrock. This drainage explains the drop in natural fluid potential in the aquifer towards the northeast. The increase in natural fluid potential towards the southwest supports the writer's conclusion on page 18 concerning the direction and location of the buried valley outlined on figure 4. If the course of the buried valley were south, the natural fluid potential in the buried valley aquifer would probably decrease toward the location where the buried valley crosses the North Saskatchewan River valley.

Groundwater Availability in the Bedrock Deposits

The aquifers in the bedrock materials are thin sandstones and coal seams. The top of bedrock occurs at depths ranging from 60 to 140 feet over the area where buried valleys are not present. In the lower part of the buried valley on figure 4 the top of bedrock is at 180 to 215 feet below surface. Water-well drillers' reports indicate that yields up to 10 imperial gallons per minute can be obtained from

the more permeable aquifers in the bedrock but generally the yields from wells completed in bedrock aquifers are lower.

Natural Recharge, Discharge, and Drainage of Aquifers in the Surficial and Bedrock Deposits

Recharge and discharge are here considered in the sense defined by Toth (1963) as the processes in which water is exchanged between the saturated zone and either the atmosphere or the zone of aeration. These processes should not be confused with the meaning of recharge and discharge as used in the study of the saturated flow of groundwater.

Precipitation is the source of natural recharge of water to the groundwater reservoir in the area. The high water table in the area of aeolian deposits is expressed by perennial sloughs in many of the interdune low areas. The high water table coupled with relatively high infiltration capacities of the sandy deposits at the surface results in rapid rises of the water table in response to precipitation. A water-table well located in Lsd. 8, Sec. 12, Tp. 51, R. 26, W. 4th Mer. is equipped with an automatic water-level recorder. The writer was at the recorder site and noticed that the water level in the observation well was rising due to heavy rainfall on June 3 and again on June 17, 1965. The hydrograph shows a rapid rise of about 0.40 foot in water level as a result of rainfall on each of the two days. The well is 25 feet in depth and the water table only a few feet below surface. The rise in water level on June 17 was calculated by the writer to begin in less than two hours after rainfall started. The scale of the hydrograph prevented a more accurate time determination for the beginning of the rise. A comparison of week-end water level measurements with total weekly precipitation is shown on figure 37. The precipi-

tation data were obtained from monthly records of meteorological observations for the Canada Department of Transport's meteorological station at the Edmonton International Airport. The airport is located about 7 miles southeast of the town of Devon. Figures 37 and 38 show that the main rise in the water table occurs in the spring. The water level declines during the summer and fall, except for peaks due to precipitation, and declines steadily through the winter months. The spring rise is a result of the infiltration of water from melting snow to the saturated zone. The net amount of water available for infiltration is higher in the spring than other seasons because the area is mainly one of internal drainage and evapotranspiration losses are low. The decline trend of water levels during the summer reflects the small amounts of water available for infiltration because of high evapotranspiration losses. When the intensity of rainfall is high or the period of rainfall is long, soil moisture deficiencies are filled and water is available to infiltrate to the saturated zone. The availability of water for infiltration, coupled with a high water table and permeable sands at the surface, results in peaks on hydrographs during the summer and fall seasons. Decline during the winter months is a result of the subsurface movement of water in the zone of saturation. Groundwater is discharged throughout the year by seepage and spring discharge along the North Saskatchewan River valley where the aquifers crop out along the valley sides.

Aquifer Evaluation of Unit A

The aquifer evaluation program consisted of three phases: (1) test drilling, (2) well completion, and (3) pump testing.

Test drilling is probably the most important part of a program of aquifer evaluation because it establishes the existence and location of the aquifer and pro-

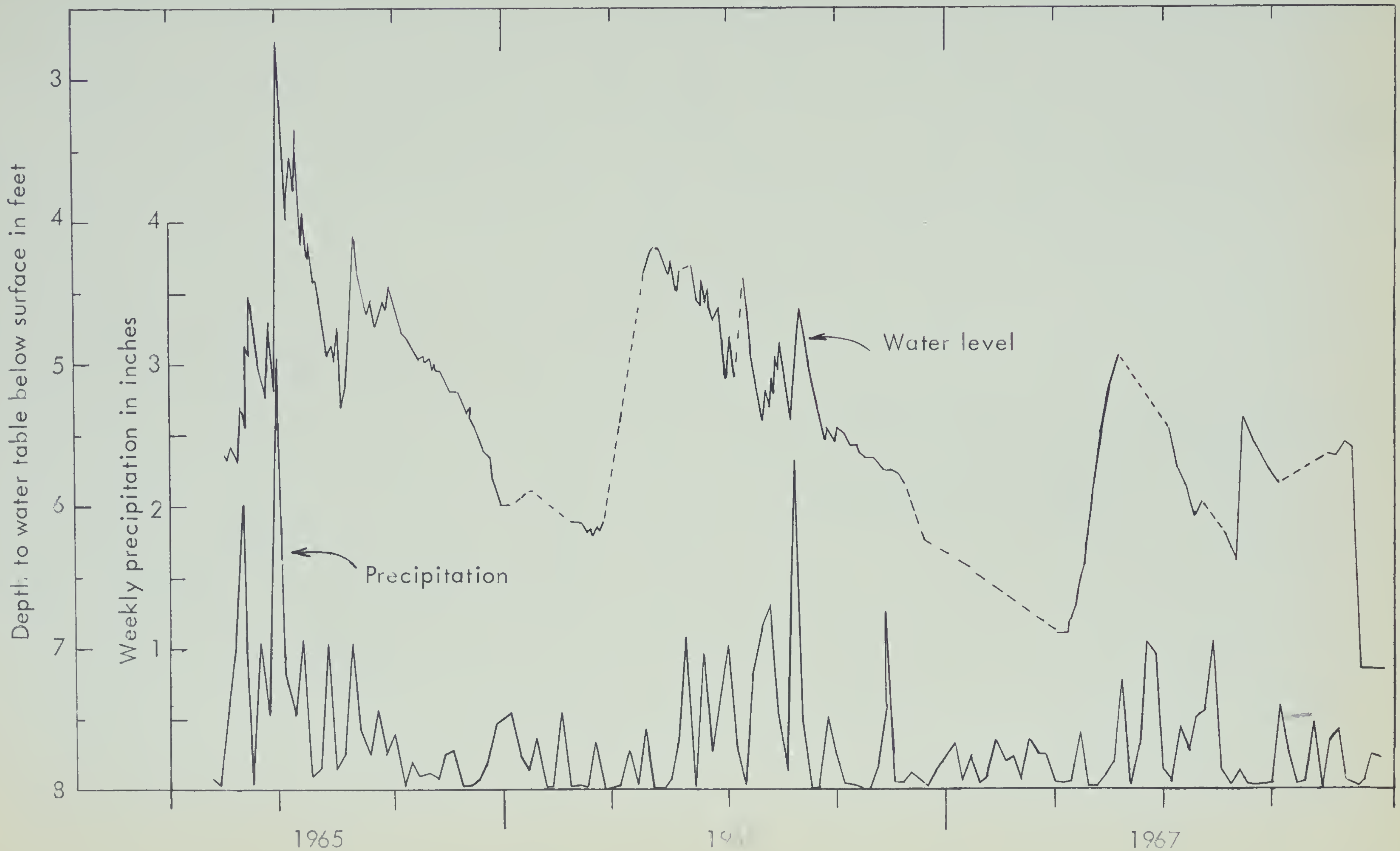


Figure 57. Total weekly precipitation and hydrograph for Devon Observation Well No. 2

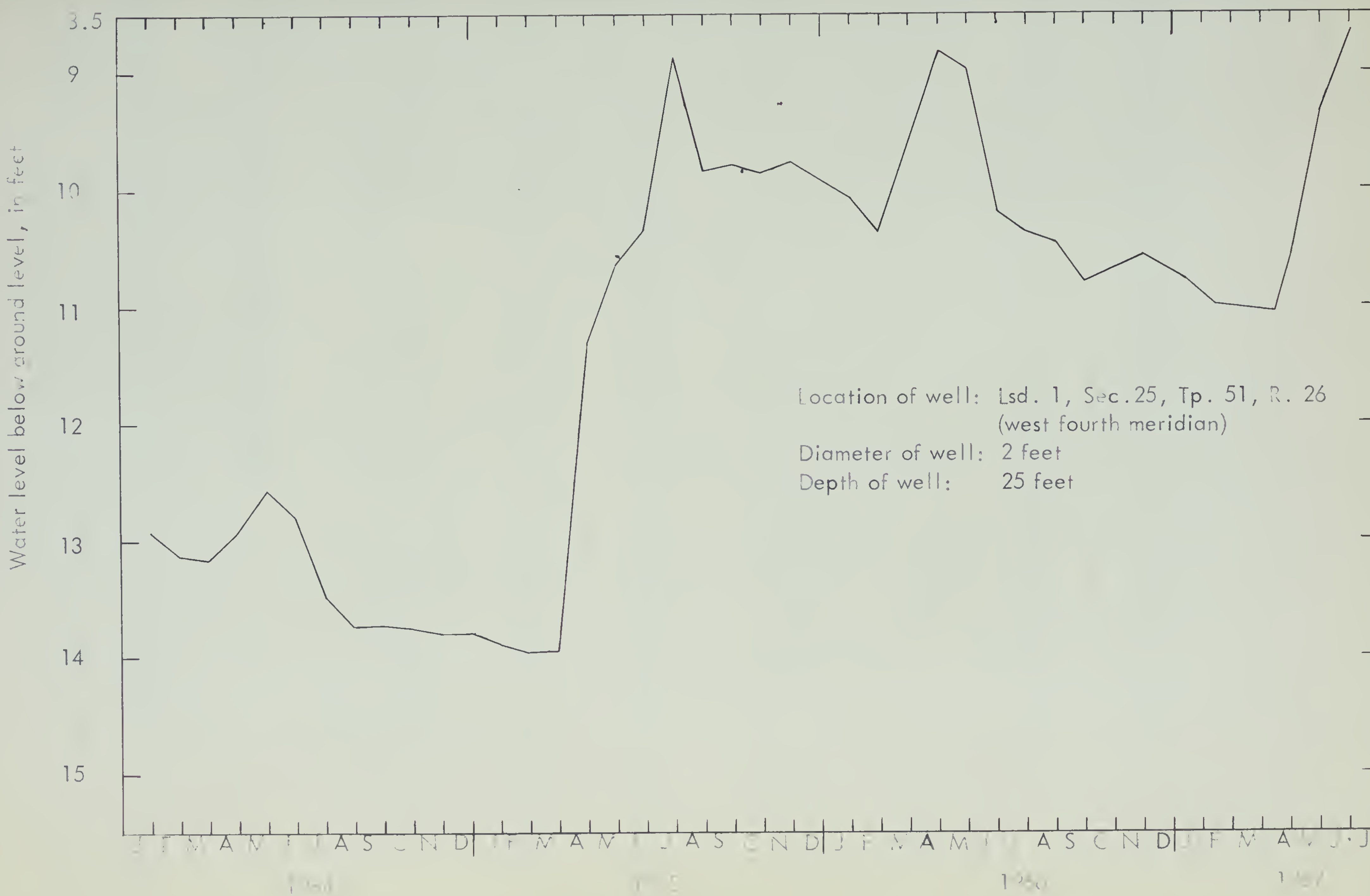


Figure 38. Month-end water level in a large-diameter shallow well

vides samples of the aquifer at the point where the well is constructed. The success of well design depends principally on the representativeness of samples of the aquifer material obtained. Care in sampling cannot be over-emphasized. Information from test drilling also indicates the type of aquifer present and the hydrogeologic boundaries that are associated with it, if any. The number of observation wells necessary in a pumping test to properly evaluate the potential of an aquifer is based on the type of aquifer and on the probable hydrogeologic boundaries present.

Three test holes, 65-1, 65-2, and 65-3, were drilled to locate and prove the existence of the buried valley. Test holes 65-1 and 65-2 were on the edge of the buried valley or on higher level terraces adjacent to it. Test hole 65-3 was situated in the buried valley (Figs. 4 and 7). A fourth test hole (65-4) was drilled at a later date by V. A. Carlson of the Groundwater Division, Research Council of Alberta. This test hole was also in the buried valley (Figs. 4 and 7).

On the basis of this information it was decided to complete a well at test hole 65-3 using the samples obtained during test drilling for the purpose of well design. The evaluation of an aquifer with two barrier boundaries requires at least three observation wells to locate "effective" barrier boundaries from pumping test data (Walton, 1962). The boundaries are called "effective" boundaries because they are in reality hypothetical but they reflect the presence of a complex feature of nature.

Completion of Pumping and Observation Wells

Well completion consists of three steps: (1) well design, (2) well construction, and (3) well development. Each step is equally important but well development is the one that is often neglected. Ahrens (1957) presented complete well design

criteria based on case histories of high capacity wells in the western United States. However, these design criteria are applicable anywhere. Well design essentially involves the choice of casing diameter and well screen diameter, length and slot size. The selection of a "gravel" pack may also be required. Screen slot size is based on the grain size distribution analysis of the aquifer material if no pack is used. If a pack is used the slot size is based on the size of the pack material and the selection of pack material is based on the analysis of the aquifer material.

A slot size of 0.008 inches in width was required for optimum well design according to Ahrens' (1957) criteria. This slot size would retain about 75 per cent of the aquifer material. The relatively uniform grain size distribution of the aquifer material and the thickness of the aquifer made it possible to depart somewhat from Ahrens' design criteria and a slot width of 0.010 inches was used instead. This would retain about 50 per cent of the aquifer material. Optimum well design for the aquifer materials also requires that a uniform grain-size pack be used according to Ahrens (1957) but, for economic reasons, a pack was not used.

The length, diameter, and type of well screens used in the construction of the wells are illustrated in figure 39, as are the sizes of casings used.

Where an observation well is open to only part of an aquifer, partial penetration effects may distort the drawdown in the well and complicate the interpretation of the pumping test data. To avoid this wells are usually placed at a distance from the pumping well at which partial penetration effects become negligible. Walton (1962) presented criteria for determining this distance. The locations of observation wells with respect to the pumping well are shown on figure 40.

Development involves the process of surging water back and forth through

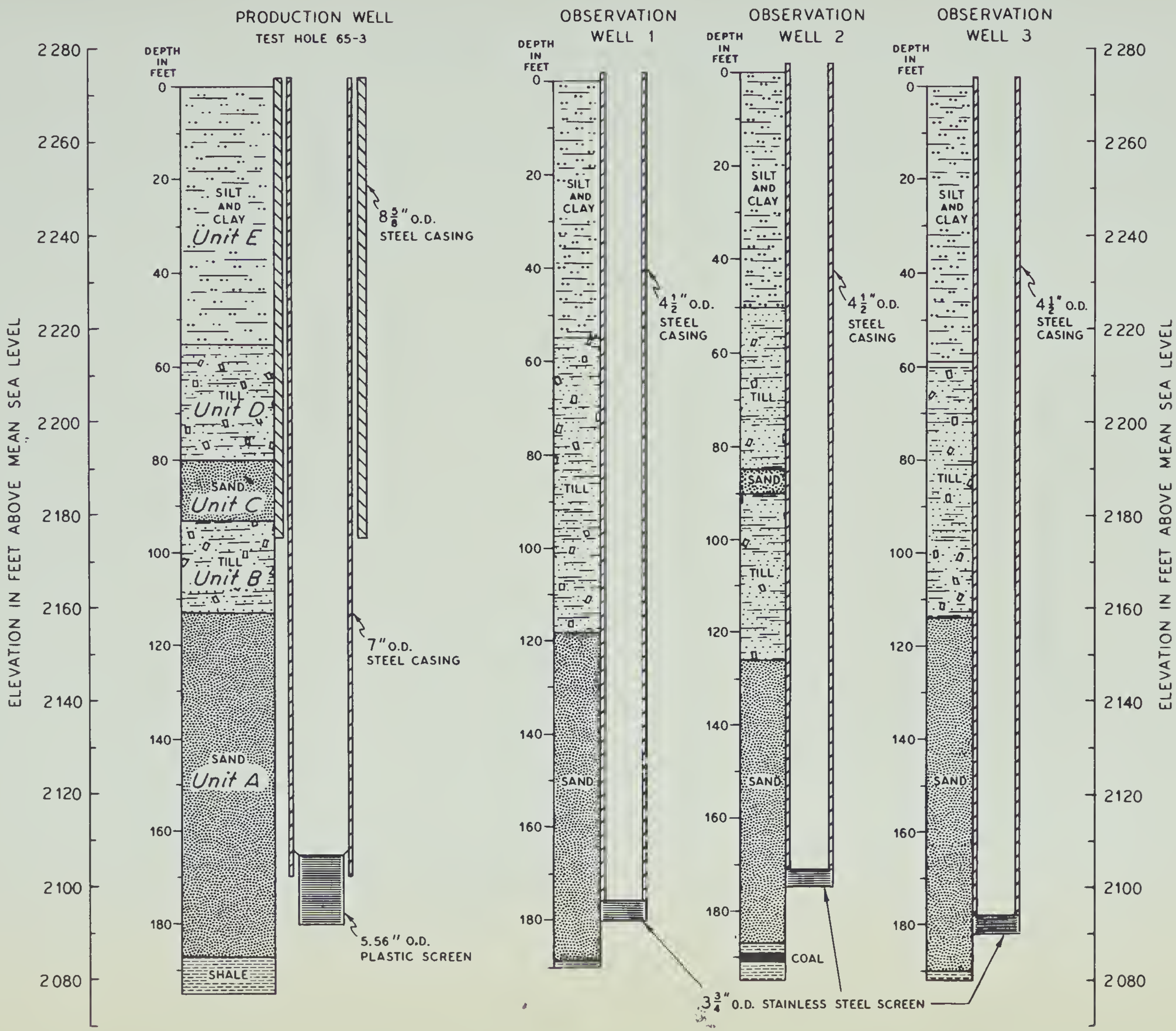


Figure 39. Graphic logs and completion details of production well and observation wells

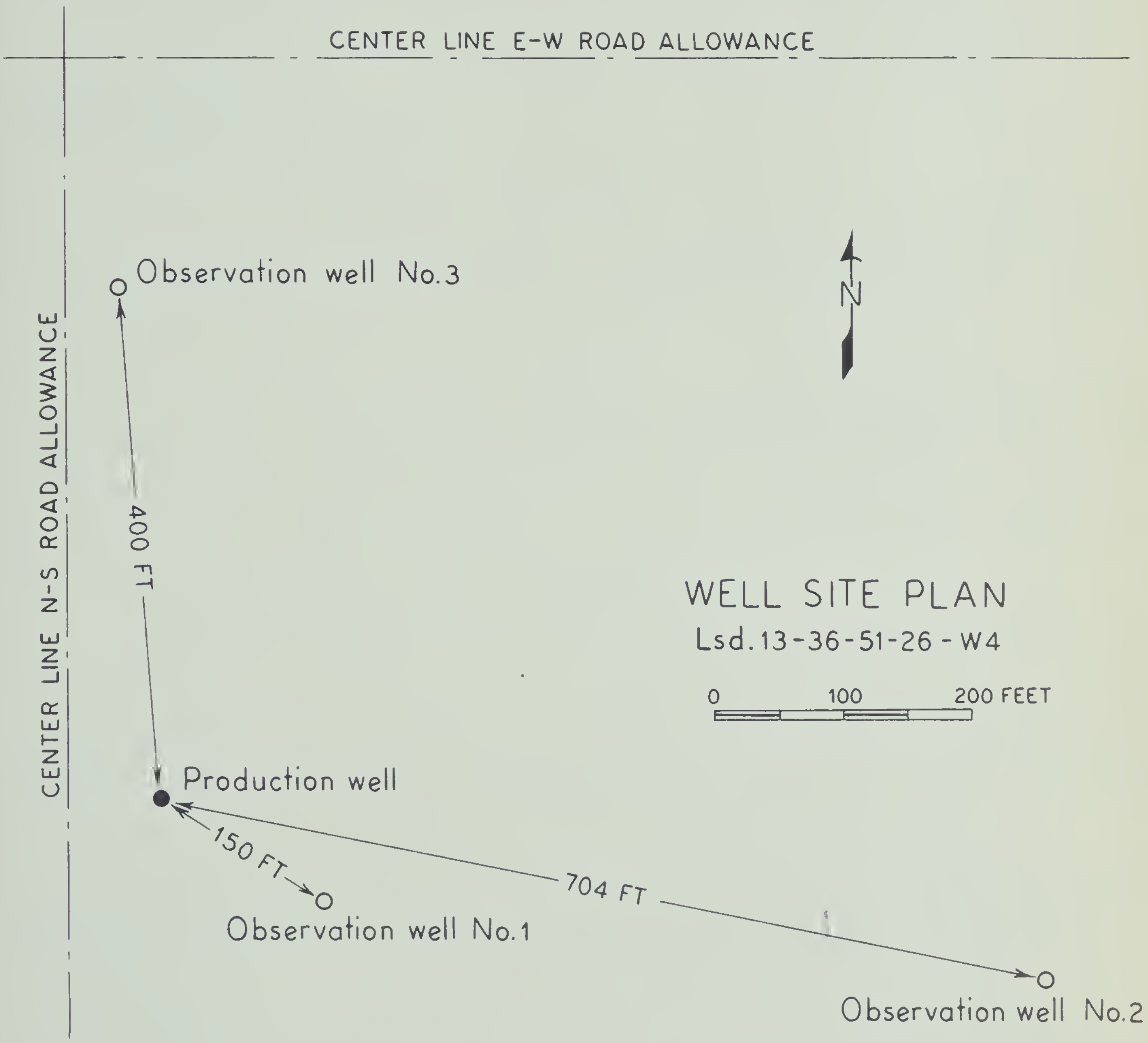


Figure 40. Well site plan

the well screen in order to stabilize the materials surrounding the screen. The surging removes fine particles from the aquifer material in the vicinity of the well and creates an envelope of material which grades from coarse material next to the screen to the gross size of the aquifer materials. This creates a stable condition resulting in a sand-free well, regardless of the rate at which the well is pumped in the future. Well development in the wells was accomplished with the use of a bailer and a solid surge block.

Bailing Test and Pumping Test

Basic aquifer-testing procedures have been outlined by Jones (1963) and the procedures are essentially those followed during the present aquifer investigation. A 90-minute bailing test was carried out in the pumping well at 20 imperial gallons per minute and time-drawdown and time-recovery measurements were taken in observation well 1. The graph of drawdown and recovery of water levels in observation well 1 during the bail test is plotted on figure 41.

From the bail-test data approximate drawdowns in the observation wells that would take place at the rate the production well would be pumped during the pumping test were calculated. This information was required to estimate the length of cable necessary to set up float-type automatic water-level recorders on observation wells 1 and 2 to measure time-drawdown and time-recovery of water levels during the pumping test. The water levels in observation well 3 were measured manually. The discharge rate of the pumping well was measured using a 45-gallon drum with a flap-valve. The time necessary to fill the drum with water was recorded with a stop watch. Plate 8 shows the pumping test in progress. Water was discharged in a nearby perennial creek. The low permeability of lacustrine clays and tills over-

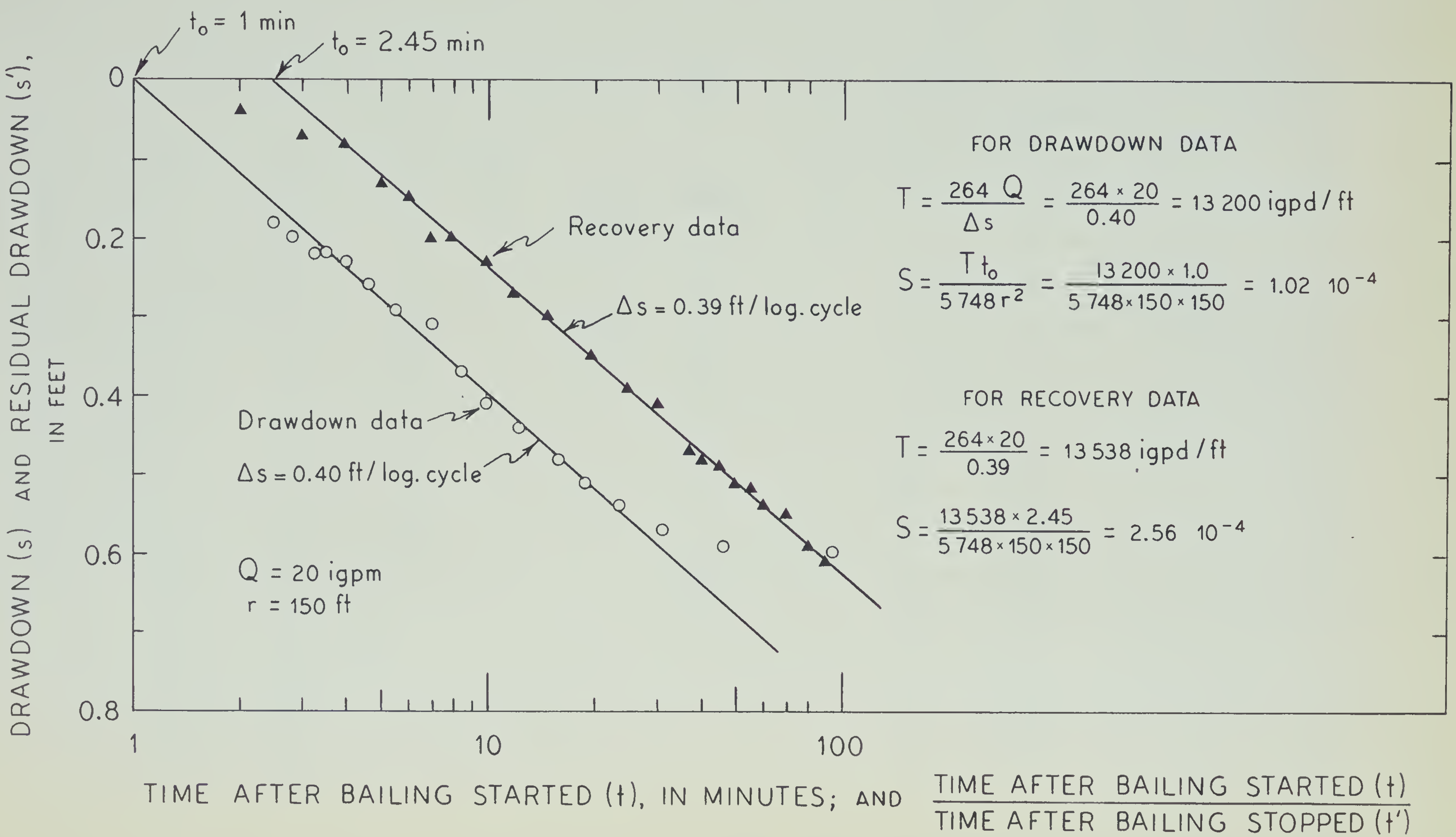


Figure 41. Graph of drawdown and recovery of water level in Observation Well No. 1, Bail Test No. 1

lying the aquifer and the length of the pumping test suggest that water in the creek would not affect the drawdown of water levels in the observation wells.

The pumping test was conducted for 60.5 hours at an average rate of 76.4 imperial gallons per minute. The maximum variation in pumping rate was 4 per cent.

The time-drawdown data in observation wells 1, 2, and 3 are plotted on figures 42, 43, and 44, respectively. Time-drawdown and time-recovery data for the pumping well are plotted on figure 45.

Theory of Aquifer Testing and Pumping-Test Data Analysis

The Nonequilibrium or Type-Curve Method

Theis (1935) introduced the nonequilibrium equation in the form

$$s = \frac{114.6QW(u)}{T} \tag{1}$$

where

$$W(u) = \int_u^{\infty} \frac{e^{-u}}{u}\, du = -0.5772 - \ln u + u - \left(\frac{u^2}{2.2!}\right) + \left(\frac{u^3}{3.3!}\right) - \left(\frac{u^4}{4.4!}\right) \ldots$$

and

$$u = \frac{2242r^2S}{Tt} \tag{2}$$

s = drawdown in observation well in feet

Q = discharge, in imperial gallons per minute (igpm)

T = coefficient of transmissivity, in imperial gallons per day per foot (igpd/ft)

r = distance from observation well to pumped well, in feet

S = coefficient of storage, dimensionless

t = time after pumping started, in minutes

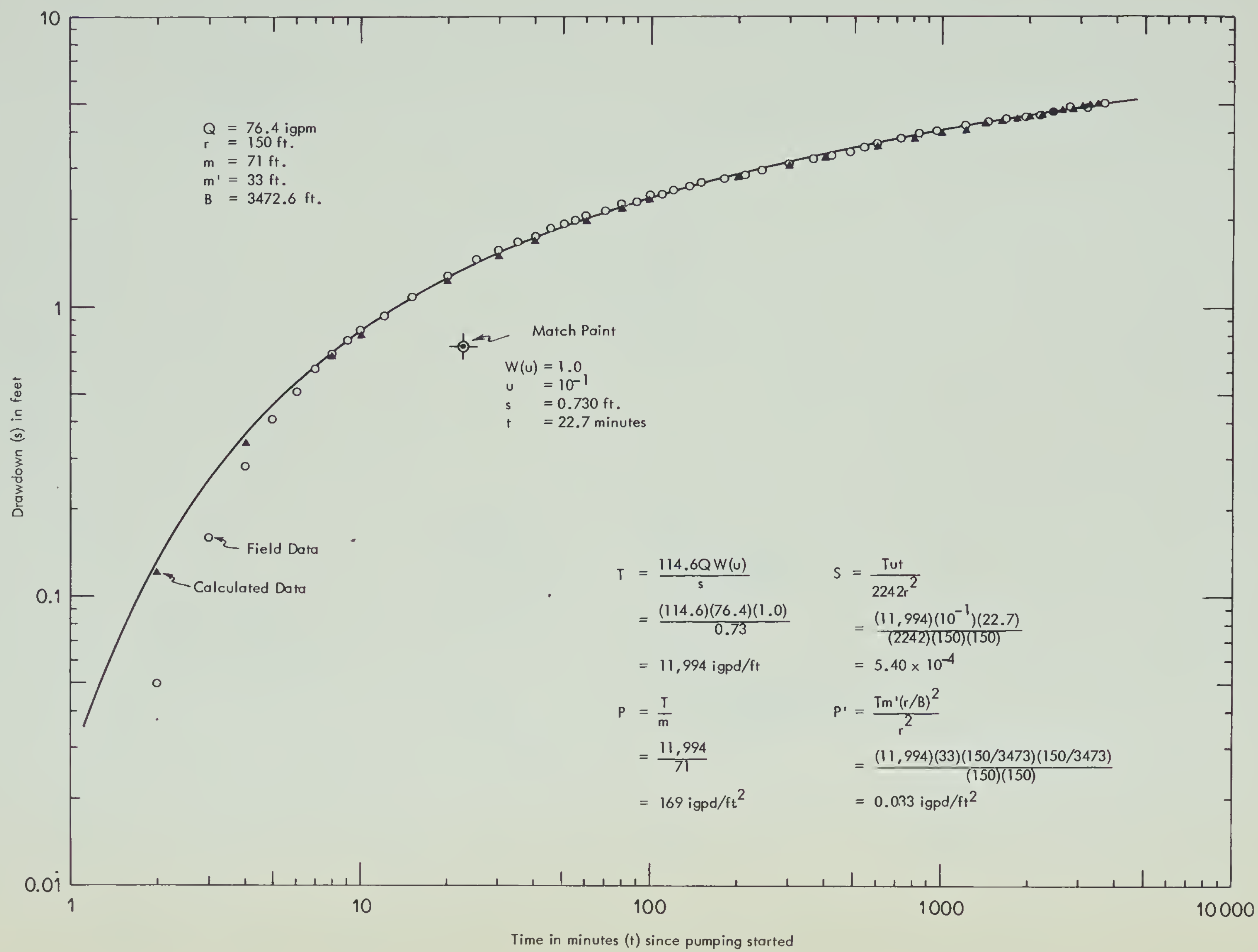


Figure 42. Time-drawdown graph of water level in Observation Well No. 1, Pumping Test

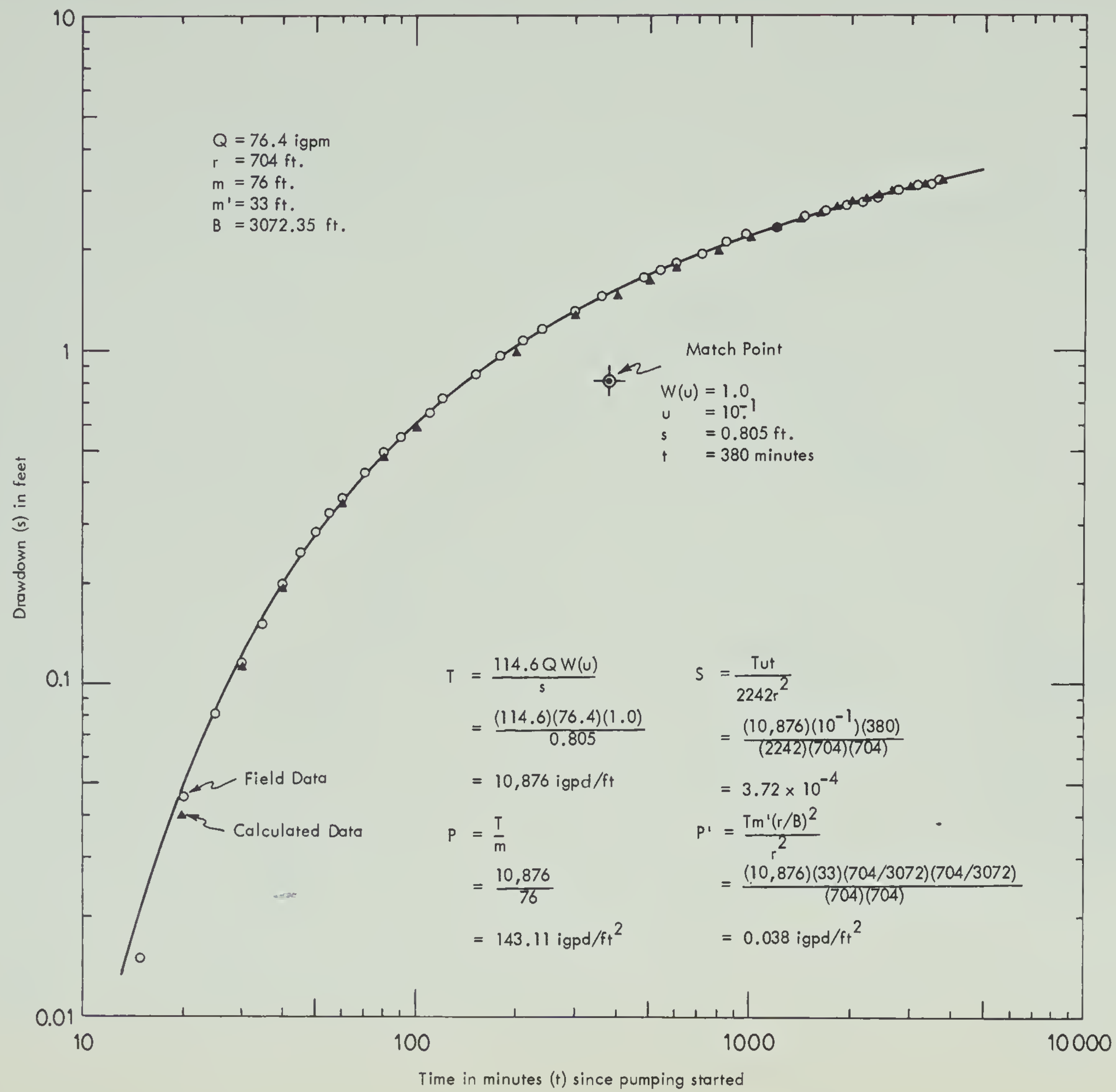


Figure 43. Time-drawdown graph of water level in Observation Well No. 2, Pumping Test

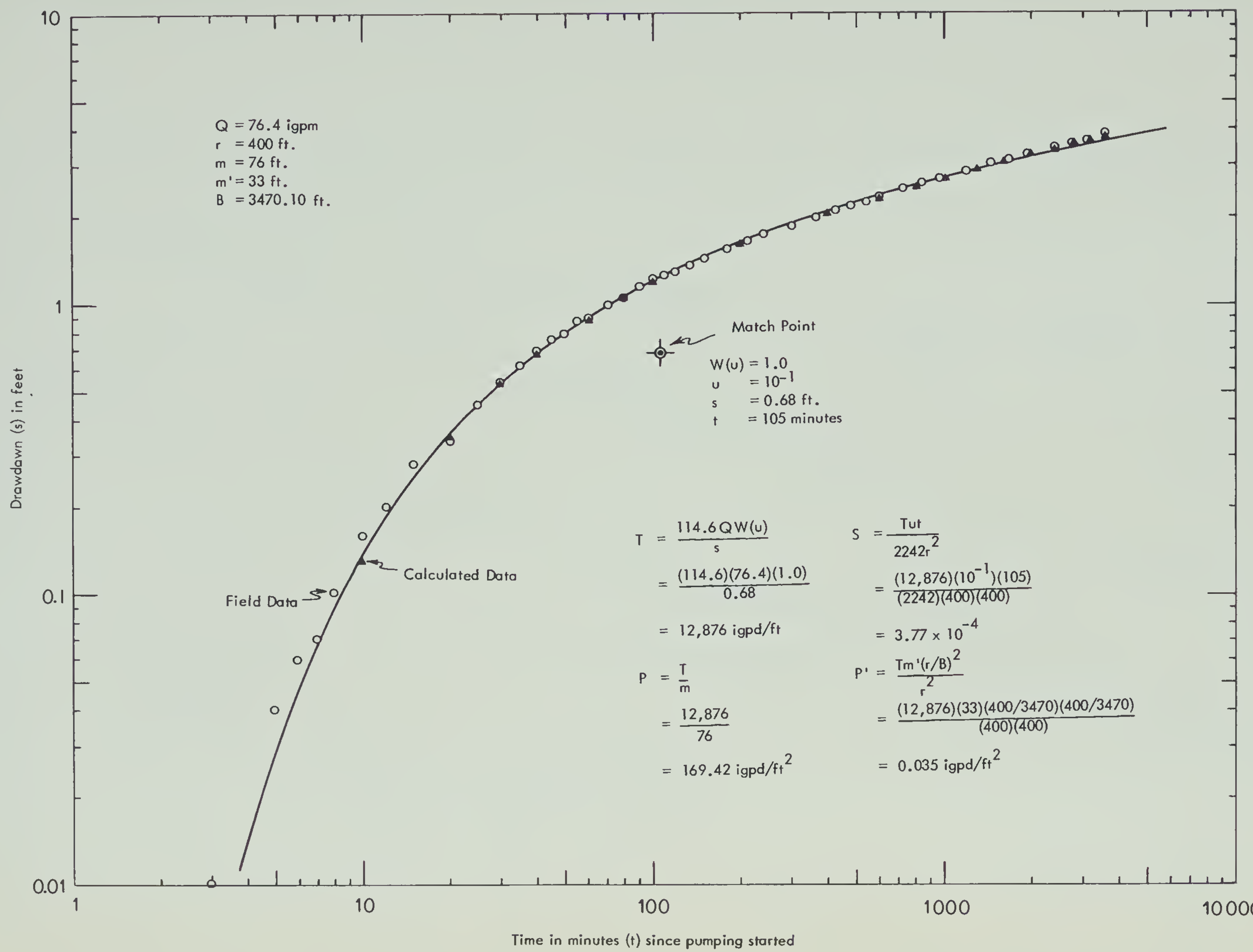


Figure 44. Time-drawdown graph of water level in Observation Well No. 3, Pumping Test

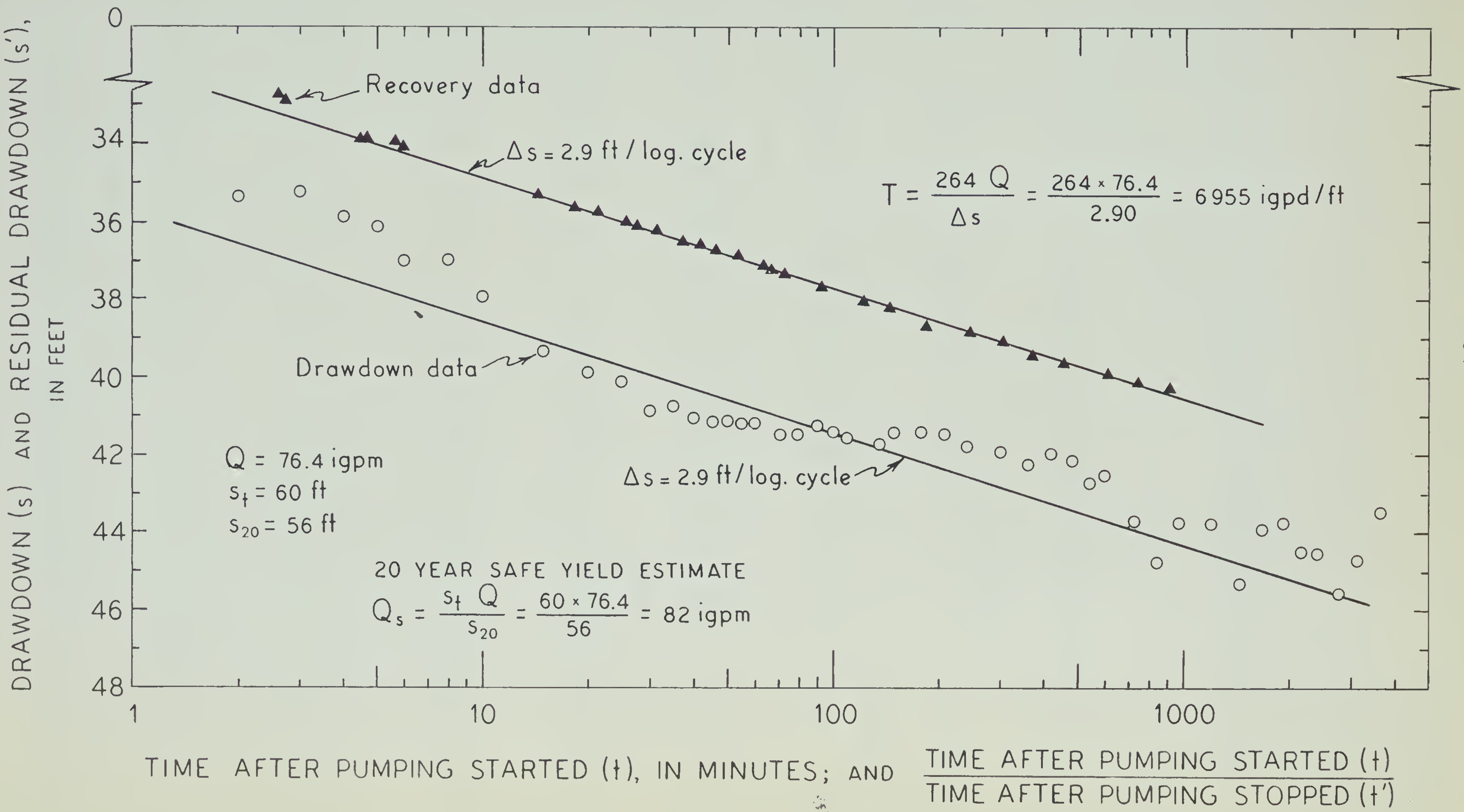


Figure 45. Graph of drawdown and recovery of water level in the pumping well (T.H. 65-3)

W(u) is known as the "well function." The equation $s = \frac{114.6QW(u)}{T}$ is also known as the nonleaky artesian formula. Hantush and Jacob (1955) derived the leaky artesian equation. This equation differs from the nonleaky artesian euqation by the introduction of a complicated "well function for leaky artesian aquifers" which is written W(u,r/B) where

$r/B = r/\sqrt{T/(P'/m')}$

P' = coefficient of vertical permeability of the semiconfining bed, in imperial gallons per day per square foot (igpd/sq ft)

m' = thickness of confining bed through which leakage occurs, in feet

Walton (1962) plotted values of W(u,r/B) versus 1/u on log-log paper. These curves are known as the "nonsteady state leaky artesian-type curves." Solution of pumping-test data is accomplished by plotting the field data of drawdown versus time on log-log paper and placing the graph over the nonsteady state leaky artesian-type curves until a best fit is obtained. Appropriate match point coordinates of W(u,r/B), 1/u, s, and t are placed in equations (1) and (2) above to determine values of transmissivity and storage coefficients.

Bukhari _et al._ (1968) developed a computer program in which iterative adjustment of B takes place until observed and predicted drawdowns match with some specified limit of accuracy. The T and S values used in the program are calculated from early time-drawdown data assuming that part of the data is unaffected by boundaries or leakage. These values are calculated for observation wells 1, 2, and 3 on figures 42, 43, and 44, respectively. It was necessary to calculate T and S in this manner from the pumping test data because the tendency of the time-drawdown curve in the pumping well to flatten (Fig. 45) and calculation of image well effects

at the pumping test site show that barrier boundary effects and leakage effects are both present in the time-drawdown data for the observation wells. This excludes the possibility of standard curve-matching solutions for the location of effective barrier boundaries and the leakage factor B. The leakage factor B is defined as

$$B = \sqrt{\frac{Pmm'}{P'}}$$

where P = the coefficient of permeability of the main aquifer in igpd/ft^2

P' = the coefficient of vertical permeability of the semiconfining stratum in gpd/ft^2

m = thickness of the main aquifer in feet

m' = thickness of the semiconfining stratum in feet.

The locations of the effective barrier boundaries had to be established as accurately as possible as this information was also required for the computer analysis. The locations of the boundaries were estimated on a basis of the available geological information and the limits of a hypothetical infinite-strip aquifer system are shown on figure 46. The geological information showed that 1) the south wall of the buried valley is situated somewhere between test holes 65-2 and 65-3, 2) the north wall is situated between test hole 65-4 and a point approximately 3/4 of a mile north of test hole 65-4, and 3) the course of the buried valley is in a northeasterly direction. This estimate of boundary locations proved to be excellent as the time-drawdown data for each observation well calculated in the computer analysis fitted the field data very accurately (Figs. 42, 43, and 44). The close agreement of calculated data with field data is probably a consequence of the steep-walled character of the buried valley which results in hypothetical boundaries being effectively coincident with the actual hydrogeologic boundaries. The average calculated value of

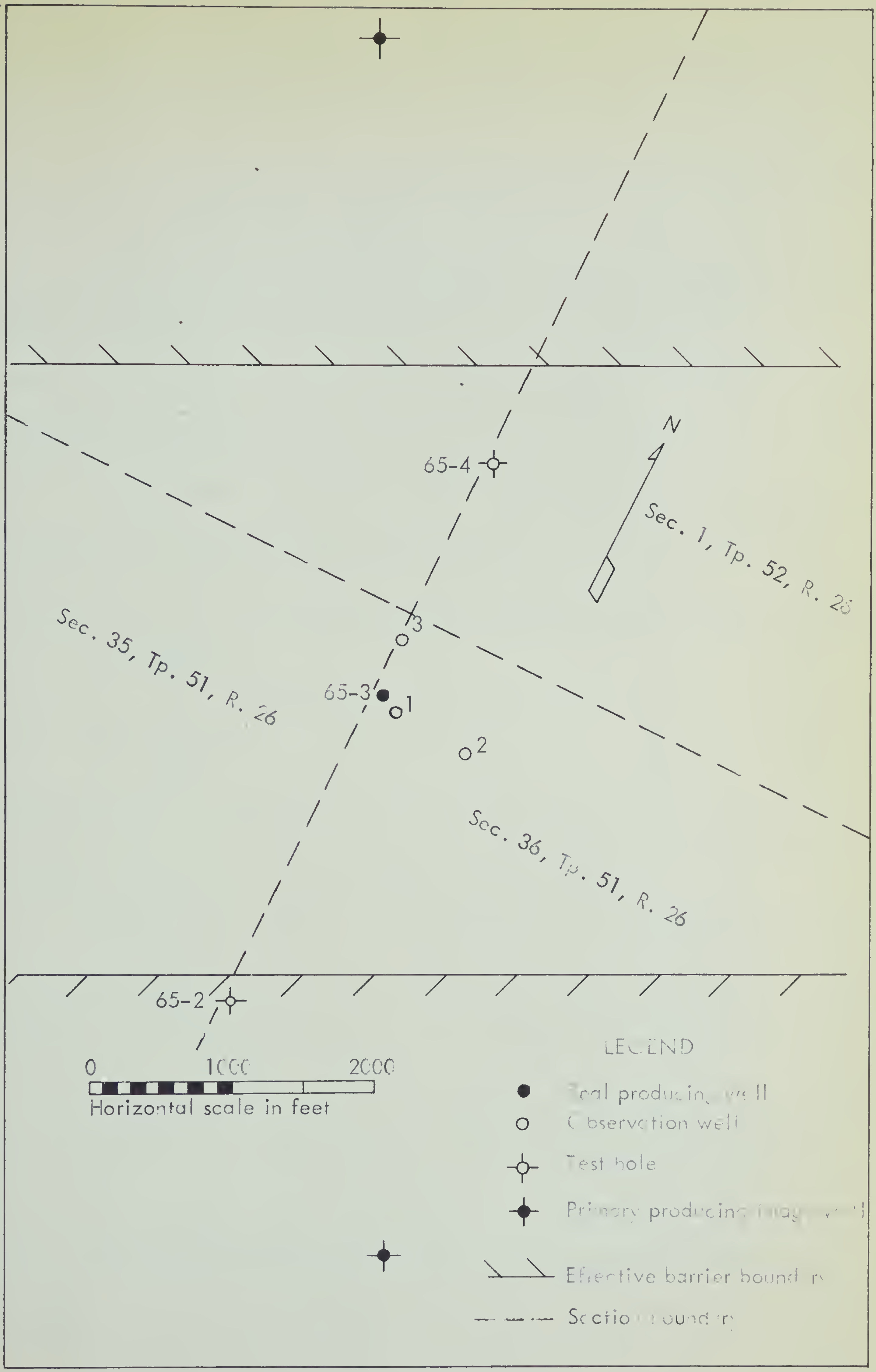


Figure 46. Limits of a hypothetical aquifer system based on geologic information

B was 3,338 feet. This value of B and average values of 11,915 gpd/ft for T and 4.30×10^{-4} for S were used to calculate by computer analysis drawdown at radial distances up to 10,000 feet from a single well pumping continuously at various rates for a 20-year period (Fig. 47). The distance-drawdown curves show the drawdown for a well with an effective radius of 1 foot and an efficiency of 100 per cent. An efficiency of 100 per cent means no head loss in the well results from the friction of water moving through the screen slots and inside the well.

The Modified Nonleaky Artesian Equation or Straight Line Method

Jacob (1946) recognized that when u becomes small (less than 0.01) the sum of the terms in W(u) beyond the natural logarithm of u becomes insignificant. Cooper and Jacob (1946) derived the equations listed below for calculating T and S.

$$T = 264Q/\Delta s$$

$$S = \frac{Tt_o}{5748r^2}$$

where Δs = drawdown difference per log cycle, in feet, and t_o = the intersection of the straight-line slope with the zero drawdown axis, in minutes.

Field data are plotted on semi-log paper for a graphical solution of T and S. The graphs of time-drawdown and time-recovery for observation well No. 1, bailing test No. 1, are plotted on figure 41. Rough estimates of T and S are also shown on the figure. These values were reasonably good ones for first estimates of T and S based on a 90-minute bail test. The time-drawdown plot (Fig. 41) also indicates leakage effects. Only a value of T can be calculated for the pumping well because r is not known. The time-drawdown plot for the pumping well also indicates leakage effects (Fig. 45).

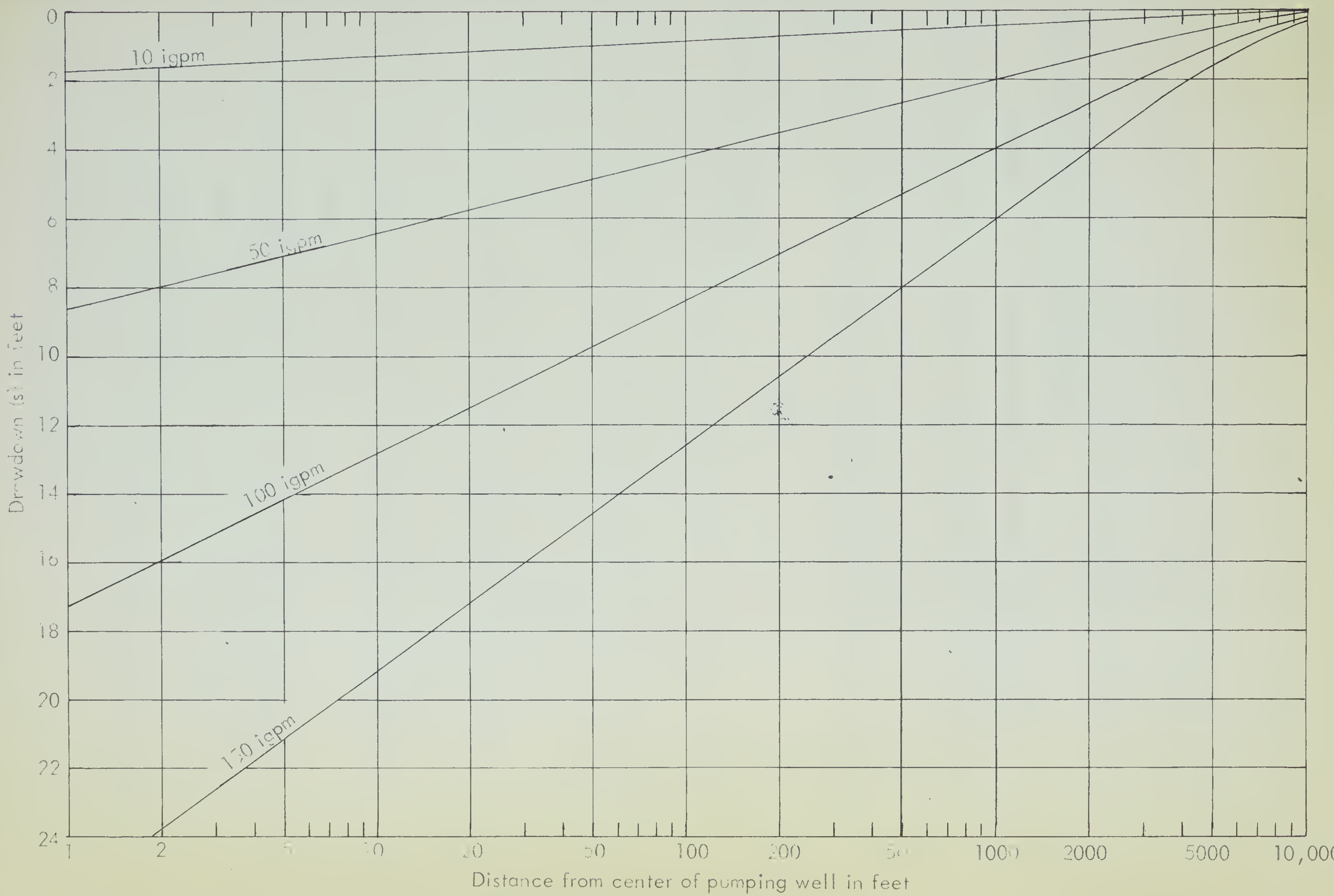


Figure 47. Distance-drawdown graph for continuous pumping of a single well over a 20-year period

Permeability of the Aquifer

Transmissivity is related to permeability by the equation $T = mP$, where m equals the saturated thickness of the aquifer in feet and P is the coefficient of permeability of the aquifer in imperial gallons per day per square foot (igpd/sq ft). An average value for P of 160.5 gpd/sq ft was calculated from the pumping test data.

Vertical Permeability of the Leakage Bed

Although P' is defined as the coefficient of vertical permeability of the confining bed overlying the aquifer, it is here considered to be the coefficient of vertical permeability of the leakage bed which at the pumping test site consists of Units B and C. The average value of P' calculated from the pumping test data was 0.035 igpd/sq ft.

Safe Yield of the Pumping Well

Safe yield is here defined as the rate at which the pumping well can be pumped continuously for a 20-year period without drawing the water level in the well below the top of the aquifer. This rate is calculated for the pumping well using the straight-line plot of time-drawdown and the equation $Q_s = \frac{s_t Q}{s_{20}}$, where

Q_s = the safe pumping rate in imperial gallons per minute (igpm)

s_t = the total available drawdown in feet. This is equal to the difference between the top of the aquifer and the nonpumping water level in the well.

s_{20} = the total, in feet, of drawdown over 7 log cycles (about 20 years) and the value of drawdown found by extrapolating the straight line to time equal to one minute.

The value calculated for the safe pumping rate of the pumping well was 82 igpm. The calculation is shown on figure 45.

Well Field Development

The safe yield of any single well will have to be adjusted for each and every additional well that is completed in the buried valley aquifer. This adjustment in pumping rate would depend on the number of wells in a well field, the spacing of the wells, and the location of the wells in the buried valley aquifer. In general, the average safe rate for each well would decrease with an increasing number of wells in the field.

For each new well site a pumping test should be carried out to determine T, S, and boundary conditions at the site, particularly for high capacity wells from which long-term production is desired.

Summary of Groundwater Availability

Sands of Unit A in the buried valleys are the best aquifers in the area. A pumping test carried out on a well completed in the buried valley aquifer indicates it will yield quantities of water up to at least 82 gallons per minute to a properly completed well. The well could be pumped continuously at this rate for 20 years without drawing the water level below the top of the aquifer. The sands in the buried valley are usually encountered at depths of more than 100 feet below surface. The natural fluid potential drops in the aquifer from the southwest to the northeast in the area, indicating the aquifer is being drained along the North Saskatchewan River to the northeast at a point where the present river valley intersects deposits in the buried valley.

Unit C contains sand aquifers in which wells can be completed that would produce 5 to 15 gallons per minute. The more permeable sand aquifers in this unit are usually a few feet in thickness and are encountered in the depth range

from 50 to 150 feet below surface in the area.

Units E and F contain the poorest aquifers which are found at depths less than 50 feet below surface. Wells completed in these aquifers will yield up to 5 gallons per minute but long periods of pumping will probably result in aquifer depletion. Wells completed in aquifers in Units E and F were observed to show marked fluctuations of water level in response to the seasons and to heavy periods of rainfall.

Recommendations

Accurate logs and samples of materials penetrated during drilling and electric logging of test holes will enable proper completion of wells drilled in surficial deposits of the area. Water wells that are designed, constructed, and developed properly should be sand free and give long service lives.

Thorough test drilling and aquifer evaluation by pump testing should preceed the installation of high capacity wells in the buried valley aquifers. Proper well design, construction, and development are imperative if long periods of continuous pumping at high rates are desired.

The spacing and number of wells installed in a well field producing from the buried valley aquifer must be carefully planned and based on sound geologic and hydrologic data.

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Plate 1a. Drive sampler

Plate 1b. Drive sampler cores showing boundary between glaciolacustrine and till deposits

Plate 2a. View of North Saskatchewan River section showing stratigraphic positions of Units A to F. Unit E3 is about 14 feet thick.

Plate 2b. Lower part of Unit A overlying bedrock deposits. The prominent pebble layer is about 6 inches thick.

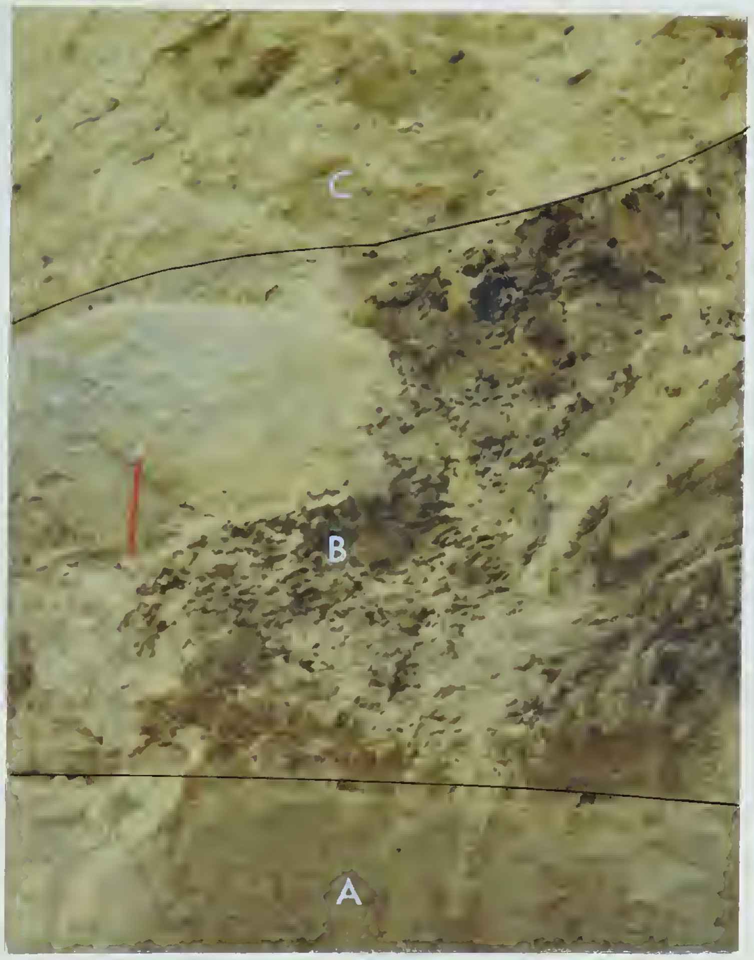

Plate 3a. Unit B overlying Unit A.

Plate 3b. Depression in Unit B filled with deposits of Unit C. The red pencil is six inches long.

Plate 4a. Glacial meltwater channel cut into the top of Unit A. Unit B has been eroded at this position.

Plate 4b. Block of bedded silts in glaciofluvial sands and gravel of Unit C.

Plate 5. Till of Unit D.

Plate 6. Deformed beds in lower part of Unit E (E1).

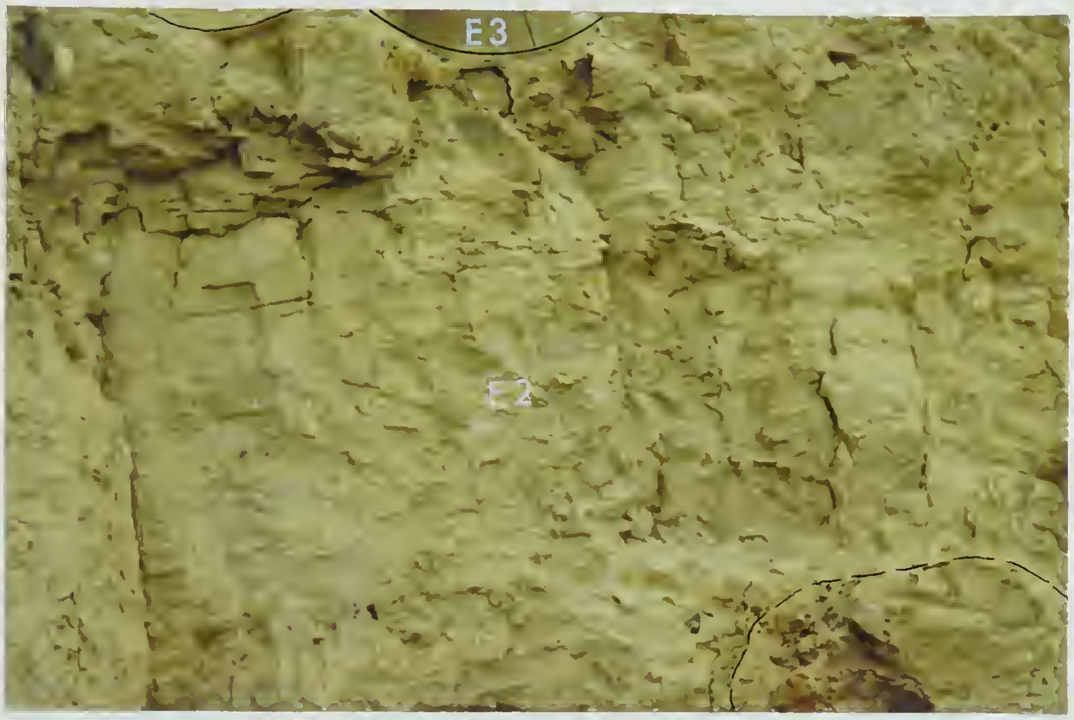

Plate 7a. Middle part of Unit E (E2) containing ice-rafted material. The large concretion in the lower right corner of the photo is about 1 foot long.

Plate 7b. Rhythmically bedded sediments in upper part of Unit E (E3) and Unit F.

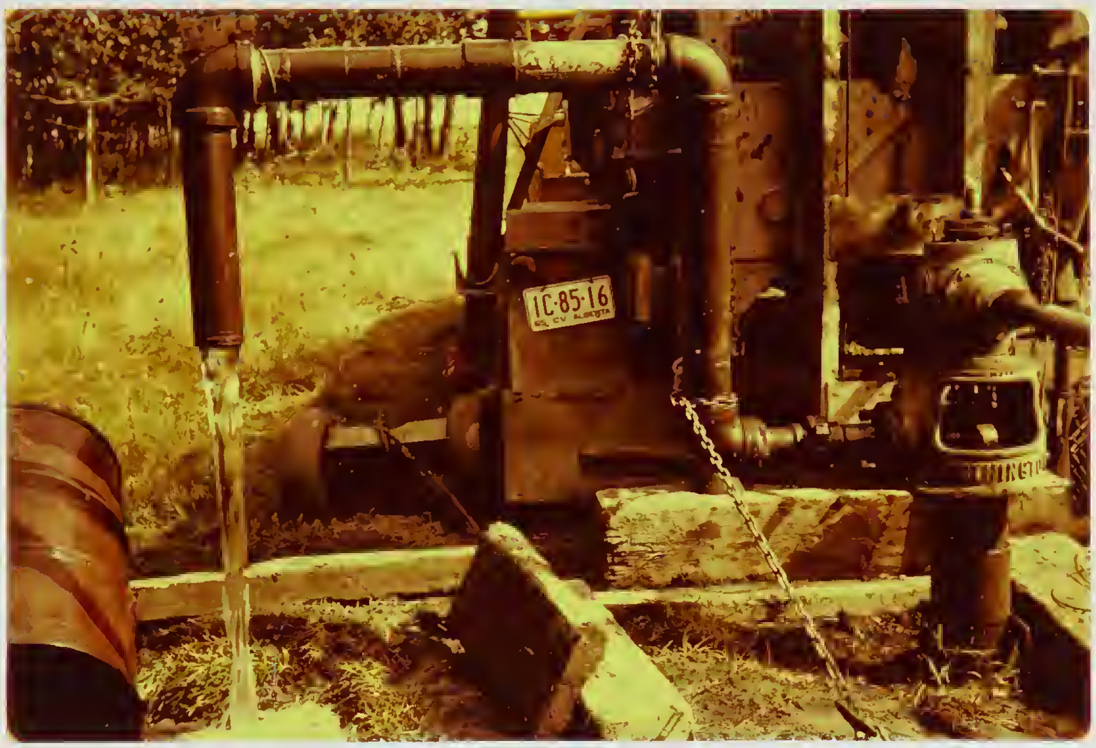

Plate 8. Pumping test at test hole 65-3.

APPENDIX A. HYDROMETER ANALYSES OF SURFICIAL DEPOSITS

Sample No. RS Unit B
50' Below surface
Sample Wt. 50 g.

Time elapsed	Hydrometer reading (A)	Composite correction (B)	Corrected reading (C=A-B)	Percentage remaining in suspension	Diameter in mm	Temp. °C
15 sec.	42.5	5.0	37.5	75.0	.087	20
30	40.1	5.0	35.1	70.2	.063	20
1 min.	38.0	5.0	33.0	66.0	.045	20
2	36.1	5.0	31.1	62.2	.032	20
4	35.1	5.0	30.1	60.2	.023	20
8	32.8	5.0	27.8	55.6	.0165	20
15	31.9	5.0	26.9	53.8	.0122	20
30	29.9	5.0	24.9	49.8	.0087	20
1 hr.	28.0	5.0	23.0	46.0	.0062	20.4
2	26.2	4.4	21.8	43.6	.0044	20.6
4	25.3	5.0	20.3	40.6	.00315	20.5
8	24.5	5.1	19.4	38.8	.00225	20.2
24	22.8	5.5	17.3	34.6	.0013	19.5

Retained on Sieve Mesh No.	Size (mm)	Sample wt. (grams)	Cumulative wt. (grams)	Cumulative wt. (per cent)
60	.250	2.41	2.41	4.82
80	.177	1.90	4.31	8.62
120	.125	2.57	6.88	13.76
170	.080	2.60	9.48	18.96
230	.063	2.47	11.95	23.90
PAN		.40	12.35	24.70

Other Data:
Sand Sample Wt. 12.79 g.

Percentage Sand	23.9
Percentage Silt	38.1
*Percentage Clay	38.0
Textural Designation	Clay Loam

*less than 2 microns

Sample No. RS Unit C
46' Below surface
Sample Wt. 50 g.

Time elapsed	Hydrometer reading (A)	Composite correction (B)	Corrected reading (C=A-B)	Percentage remaining in suspension	Diameter in mm	Temp. °C
15 sec.	28.8	3.8	25.0	50.0	.093	22.0
30	25.4	3.8	21.6	43.2	.067	22.0
1 min.	22.8	3.8	19.0	38.0	.043	22.0
2	19.3	3.8	15.5	31.0	.035	22.0
4	16.3	3.8	12.5	25.0	.025	22.0
8	15.5	3.8	11.7	23.4	.018	22.0
15	13.6	3.8	9.8	19.6	.013	22.0
30	12.3	3.9	8.4	16.8	.0094	22.1
1 hr.	10.9	3.9	7.0	14.0	.0067	22.1
2	10.0	4.1	5.9	11.8	.0047	22.6
4	9.1	4.0	5.1	10.2	.00336	22.8
8	8.2	3.7	4.5	9.0	.0024	23.0
24	8.0	4.3	3.7	7.4	.0014	21.3

Retained on Sieve Mesh No.	Size (mm)	Sample wt. (grams)	Cumulative wt. (grams)	Cumulative wt. (per cent)
60	.250	4.92	4.92	9.84
80	.177	5.52	10.44	20.88
120	.125	6.02	16.46	32.92
170	.080	5.13	21.59	43.18
230	.063	4.79	26.38	52.76
PAN		0.65	27.03	54.06

Other Data:
Sand Sample Wt. 27.09 g.

Percentage Sand	52.8
Percentage Silt	39.4
*Percentage Clay	7.8
Textural Designation	Sandy Loam

*less than 2 microns

Sample No. RS Unit C
55' Below surface
Sample Wt. 50 g.

Time elapsed	Hydrometer reading (A)	Composite correction (B)	Corrected reading (C=A-B)	Percentage remaining in suspension	Diameter in mm	Temp. °C
15 sec.	40.7	4.0	36.7	73.4	.085	21.9
30	34.4	4.0	30.4	60.8	.062	21.9
1 min.	28.8	4.0	24.8	49.6	.046	21.9
2	21.8	4.0	17.8	35.6	.034	21.9
4	16.3	4.0	12.3	24.6	.025	21.9
8	14.1	3.9	10.2	20.4	.018	21.9
15	12.4	3.8	8.6	17.2	.013	21.9
30	11.2	3.5	7.7	15.4	.0095	22.0
1	10.1	3.8	6.3	12.6	.0067	22.0
2	9.3	3.8	5.5	11.0	.0048	22.4
4	8.2	4.1	4.1	8.2	.0034	22.8
8	7.7	3.8	3.9	7.8	.0024	23.0
24	7.5	4.2	3.3	6.6	.0014	21.0

Retained on Sieve Mesh No.	Size (mm)	Sample wt. (grams)	Cumulative wt. (grams)	Cumulative wt. (per cent)
60	.250	0.21	.21	.42
80	.177	0.30	.51	1.02
120	.125	1.40	1.91	3.82
170	.080	5.06	6.97	13.94
230	.063	9.57	16.54	33.08
PAN		2.90	19.44	38.88

Other Data:
Sand Sample Wt. 19.61 g.

Percentage Sand	33.0
Percentage Silt	60.0
*Percentage Clay	7.0
Textural Designation	Silt Loam

*less than 2 microns

Sample No. RS Unit D
39' Below surface
Sample Wt. 50 g.

Time elapsed	Hydrometer reading (A)	Composite correction (B)	Corrected reading (C=A-B)	Percentage remaining in suspension	Diameter in mm	Temp. °C
15 sec.	32.7	3.7	29.0	58.0	.091	21.9
30	29.8	3.7	26.1	52.2	.065	21.9
1 min.	27.6	3.7	23.9	47.8	.047	21.9
2	24.6	3.7	20.9	41.8	.034	21.9
4	22.5	3.5	19.0	38.0	.024	22.0
8	21.0	3.5	17.5	35.0	.017	22.0
15	19.1	3.9	15.2	30.4	.013	22.0
30	17.3	3.8	13.5	27.0	.0091	22.0
1 hr.	15.9	3.9	12.0	24.0	.0065	22.1
2	14.9	4.0	10.9	21.8	.0046	22.5
4	13.5	4.1	9.4	18.8	.0033	22.7
8	12.4	3.8	8.6	17.2	.0023	23.0
24	11.9	4.6	7.3	14.6	.0014	21.0

Retained on Sieve Mesh No.	Size (mm)	Sample wt. (grams)	Cumulative wt. (grams)	Cumulative wt. (per cent)
60	.250	6.69	6.69	13.38
80	.177	3.45	10.14	20.28
120	.125	4.05	14.19	28.38
170	.080	3.91	18.10	36.20
230	.063	3.80	21.90	43.80
PAN		0.52	22.42	44.84

Other Data:		
Sand Sample Wt. 22.49 g.	Percentage Sand	44.0
	Percentage Silt	40.0
	*Percentage Clay	16.0
	Textural Designation	Loam

*less than 2 microns

Sample No. RS Unit E
12' Below surface
Sample Wt. 50 g.

Time elapsed	Hydrometer reading (A)	Composite correction (B)	Corrected reading (C=A-B)	Percentage remaining in suspension	Diameter in mm	Temp. °C
15 sec.	54.0	5.0	49.0	98.0	.079	20.0
30	52.3	5.0	47.3	94.6	.056	20.0
1 min.	51.4	5.0	46.4	92.8	.040	20.0
2	49.2	5.0	44.2	88.4	.029	20.0
4	43.9	5.0	38.9	77.8	.0215	20.0
8	35.6	5.0	30.6	61.2	.016	20.0
15	29.0	5.0	24.0	48.0	.0124	20.0
30	24.2	5.0	19.2	38.4	.0091	20.0
1 hr.	21.2	5.0	16.2	32.4	.0065	20.3
2	18.8	4.6	14.2	28.4	.0046	20.6
4	17.9	4.5	13.4	26.8	.0033	20.5
8	17.4	5.1	12.3	24.6	.00235	20.2
24	16.5	5.8	10.7	21.4	.0014	19.4

Retained on Sieve Mesh No.	Size (mm)	Sample wt. (grams)	Cumulative wt. (grams)	Cumulative wt. (per cent)
230	.063	.08	.08	.16

Percentage Sand	.2
Percentage Silt	77.9
*Percentage Clay	21.9
Textural Designation	Silt Loam

*less than 2 microns

Sample No. RS Unit E
31' Below surface
Sample Wt. 50 g.

Time elapsed	Hydrometer reading (A)	Composite correction (B)	Corrected reading (C=A-B)	Percentage remaining in suspension	Diameter in mm	Temp. °C
15 sec.	53.4	3.9	49.5	99.0	.076	22.1
30	51.0	3.9	47.1	94.2	.055	22.1
1 min.	48.2	3.9	44.3	88.6	.040	22.1
2	42.7	3.9	38.8	77.6	.030	22.1
4	33.8	3.9	29.9	59.8	.0225	22.1
8	27.2	3.9	23.3	46.6	.017	22.1
15	20.3	3.8	16.5	33.0	.0127	22.3
30	16.2	4.0	12.2	24.4	.0092	22.4
1 hr.	13.8	4.1	9.7	19.4	.0066	22.6
2	12.4	4.0	8.4	16.8	.0047	22.7
4	11.7	4.0	7.7	15.4	.0033	23.0
8	10.7	3.7	7.0	14.0	.00235	23.0
24	9.8	4.6	5.2	10.4	.0014	21.7

Retained on Sieve Mesh No.	Size (mm)	Sample wt. (grams)	Cumulative wt. (grams)	Cumulative wt. (per cent)
230	.063	0.41	0.41	.82

Percentage Sand	0.8
Percentage Silt	85.7
*Percentage Clay	13.5
Textural Designation	Silt Loam

*less than 2 microns

Sample No. RS Unit F
4' Below surface
Sample Wt. 50 g.

Time elapsed	Hydrometer reading (A)	Composite correction (B)	Corrected reading (C=A-B)	Percentage remaining in suspension	Diameter in mm	Temp. °C
15 sec.	43.5	4.0	39.5	79.0	.083	22.5
30	35.5	4.0	31.5	63.0	.063	22.5
1 min.	27.1	4.0	23.1	46.2	.047	22.5
2	21.0	4.0	17.0	34.0	.0345	22.5
4	17.1	4.0	13.1	26.2	.0225	22.5
8	15.6	4.0	11.6	23.2	.018	22.5
15	14.4	4.0	10.4	20.8	.013	22.5
30	13.6	4.1	9.5	19.0	.0093	22.6
1 hr.	13.1	4.1	9.0	18.0	.0066	22.7
2	12.4	4.1	8.3	16.6	.0048	22.7
4	11.8	3.9	7.9	15.8	.0033	23.0
8	10.9	3.8	7.1	14.2	.00235	23.0
24	10.5	4.2	6.3	12.6	.0014	21.8

Retained on Sieve Mesh No.	Size (mm)	Sample wt. (grams)	Cumulative wt. (grams)	Cumulative wt. (per cent)
60	.250	0.22	0.22	0.44
80	.177	0.62	0.84	1.68
120	.125	1.83	2.67	5.34
170	.080	4.79	7.46	14.92
230	.063	11.05	18.51	37.02
PAN		1.82	20.33	40.66

Other Data:
Sand Sample Wt. 20.30 g.

Percentage Sand	37.0
Percentage Silt	49.2
*Percentage Clay	13.8
Textural Designation	Loam

*less than 2 microns

Sample No. T.H. 67-1 Unit B
60' Below surface
Sample Wt. 50 g.

Time elapsed	Hydrometer reading (A)	Composite correction (B)	Corrected reading (C=A-B)	Percentage remaining in suspension	Diameter in mm	Temp. °C
15 sec.	44.0	3.6	40.4	80.8	.085	19.5
30	42.9	3.6	39.3	78.6	.061	19.5
1 min.	40.5	3.6	36.9	73.8	.044	19.5
2	38.5	3.6	34.9	69.8	.032	19.5
4	37.1	3.6	33.5	67.0	.0225	19.5
8	35.2	3.6	31.6	63.2	.016	19.5
15	33.3	3.7	29.6	59.2	.012	19.5
30	31.2	3.8	27.4	54.8	.0086	19.5
1 hr.	29.9	4.0	25.9	51.8	.00615	19.7
2	27.6	4.0	23.6	47.2	.0044	20.0
6	25.0	4.1	20.9	41.8	.0026	20.5
8	24.1	4.2	19.9	39.8	.0022	20.5
24	21.9	4.6	17.3	34.6	.00134	18.5

Retained on Sieve Mesh No.	Size (mm)	Sample wt. (grams)	Cumulative wt. (grams)	Cumulative wt. (per cent)
60	.250	2.44	2.44	4.88
80	.177	1.31	3.75	7.50
120	.125	2.00	5.75	11.50
170	.080	2.04	7.79	15.58
230	.063	2.25	10.04	20.08
PAN		0.16	10.20	20.40

Other Data:
Sand Sample Wt. 10.32 g.

Percentage Sand	20.1
Percentage Silt	41.6
*Percentage Clay	38.3
Textural Designation	Clay Loam

*less than 2 microns

Sample No. T.H. 67-1 Unit D
36'-40' Below surface
Sample Wt. 50 g.

Time elapsed	Hydrometer reading (A)	Composite correction (B)	Corrected reading (C=A-B)	Percentage remaining in suspension	Diameter in mm	Temp. °C
15						
15 sec.	37.0	5.4	31.6	63.2	.090	21.0
30	33.8	5.4	28.4	56.8	.065	21.0
1 min.	32.0	5.4	26.6	53.2	.046	21.0
2	30.1	5.4	24.7	49.4	.033	21.0
4	29.0	5.1	23.9	47.8	.024	21.0
8	27.1	5.1	22.0	44.0	.017	21.0
15	25.6	5.0	20.6	41.2	.012	21.0
30	23.7	4.8	18.9	37.8	.0089	21.0
1 hr.	22.1	5.0	17.1	34.2	.0064	21.0
2	20.8	5.3	15.5	31.0	.0045	21.0
4	19.0	5.0	14.0	28.0	.0032	21.5
8	17.1	5.0	12.1	24.2	.0023	22.0
24	16.7	5.1	11.6	23.2	.0014	20.5

Retained on Sieve Mesh No.	Size (mm)	Sample wt. (grams)	Cumulative wt. (grams)	Cumulative wt. (per cent)
35	.500	2.41	2.41	4.82
60	.250	4.30	6.71	13.42
80	.177	2.90	9.61	19.22
120	.125	3.37	12.98	25.96
170	.080	2.91	15.89	31.78
230	.063	2.86	18.75	37.50
PAN		.43	19.18	38.36

Other Data:
Sand Sample Wt. 19.24 g.

Percentage Sand	37.5
Percentage Silt	39.0
*Percentage Clay	23.5
Textural Designation	Loam

*less than 2 microns

Sample No. T.H. 67-1 Unit E
6'-12' Below surface
Sample Wt. 50 g.

Time elapsed	Hydrometer reading (A)	Composite correction (B)	Corrected reading (C=A-B)	Percentage remaining in suspension	Diameter in mm	Temp. °C
15 sec.	49.0	3.6	45.4	90.8	.082	19.5
30	46.6	3.6	43.0	86.0	.059	19.5
1 min.	44.2	3.6	40.6	81.2	.0425	19.5
2	38.9	3.6	35.3	70.6	.0315	19.5
4	30.9	3.6	27.3	54.6	.0235	19.5
8	25.0	3.6	21.4	42.8	.0175	19.5
15	21.9	3.6	18.3	36.6	.013	19.5
30	19.2	3.8	15.4	30.8	.0093	19.5
1 hr.	17.6	3.6	14.0	28.0	.0066	19.5
2	16.5	3.9	12.6	25.2	.0047	19.5
4	15.9	4.0	11.9	23.8	.0033	20.3
8	15.1	4.1	11.0	22.0	.00235	20.5
24	15.0	4.5	10.5	12.0	.0014	18.0

Retained on Sieve Mesh No.	Size (mm)	Sample wt. (grams)	Cumulative wt. (grams)	Cumulative wt. (per cent)
120	.125	2.34	2.34	4.68
170	.080	1.58	3.92	7.84
230	.063	1.33	5.25	10.50
PAN		0.14	5.39	10.78

Other Data:
Sand Sample Wt. 5.49 g.

Percentage Sand	10.5
Percentage Silt	68.5
*Percentage Clay	21.0
Textural Designation	Silt Loam

*less than 2 microns

Sample No. T.H. 67-1 Unit E
12'-17' Below surface
Sample Wt. 50 g.

Time elapsed	Hydrometer reading (A)	Composite correction (B)	Corrected reading (C=A-B)	Percentage remaining in suspension	Diameter in mm	Temp. °C
15 sec.	53.0	3.7	49.3	98.6	.079	19.5
30	51.0	3.7	47.3	94.6	.057	19.5
1 min.	49.3	3.7	45.6	91.2	.041	19.5
2	45.2	3.7	41.5	83.0	.030	19.5
4	39.4	3.7	35.7	71.4	.022	19.5
8	34.0	3.7	30.3	60.6	.0163	19.5
15	29.0	3.7	25.3	50.6	.0123	19.5
30	28.9	3.8	25.1	50.2	.0086	19.5
1 hr.	22.7	3.9	18.8	37.6	.0065	19.5
2	19.9	3.9	16.0	32.0	.0046	19.8
4	18.0	4.0	14.0	28.0	.0032	20.5
8	16.9	4.1	12.8	25.6	.0023	20.5
24	15.2	4.6	10.6	21.2	.0014	18.5

Retained on Sieve Mesh No.	Size (mm)	Sample wt. (grams)	Cumulative wt. (grams)	Cumulative wt. (per cent)
230	.063	0.81	0.81	1.62

Percentage Sand	1.6
Percentage Silt	76.4
*Percentage Clay	22.0
Textural Designation	Silt Loam

*less than 2 microns

Sample No. T.H. 67-1 Unit E
19'-23' Below surface
Sample Wt. 50 g.

Time elapsed	Hydrometer reading (A)	Composite correction (B)	Corrected reading (C=A-B)	Percentage remaining in suspension	Diameter in mm	Temp. °C
15 sec.	54.1	3.8	-	-	-	19.5
30	52.3	3.8	48.5	97.0	.056	19.5
1 min.	51.0	3.8	47.2	94.4	.040	19.5
2	48.0	3.8	44.2	88.4	.0295	19.5
4	43.8	3.8	40.0	80.0	.0215	19.5
8	38.3	3.8	34.5	69.0	.016	19.5
15	34.0	3.7	30.2	60.4	.012	19.5
30	29.3	3.7	25.5	51.0	.0085	19.5
1 hr.	25.3	3.8	21.5	43.0	.0064	19.5
2	22.2	3.9	18.3	36.6	.00455	19.8
4	19.9	4.0	15.9	31.9	.00325	20.4
8	17.9	4.1	13.8	27.6	.0023	20.5
24	16.2	4.8	11.4	22.8	.0014	18.5

Retained on Sieve Mesh No.	Size (mm)	Sample wt. (grams)	Cumulative wt. (grams)	Cumulative wt. (per cent)
230	.063	0.22	0.22	0.44

Percentage Sand	0.4
Percentage Silt	74.0
*Percentage Clay	25.6
Textural Designation	Silt Loam

*less than 2 microns

Sample No. T.H. 67-1 Unit E
32'-33' Below surface
Sample Wt. 50 g.

Time elapsed	Hydrometer reading (A)	Composite correction (B)	Corrected reading (C=A-B)	Percentage remaining in suspension	Diameter in mm	Temp. °C
30 sec.	54.0	3.8	-	-	-	19.5
1 min.	53.6	3.8	49.8	99.6	.039	19.5
2	53.6	3.8	49.8	98.4	.028	19.5
4	52.9	3.8	49.1	98.2	.020	19.5
8	51.2	3.8	47.4	94.8	.014	19.5
15	47.4	3.8	43.6	87.2	.0108	19.5
30	42.0	3.8	38.2	76.4	.0080	19.5
1 hr.	37.1	3.9	33.2	66.4	.0059	19.5
2	32.8	4.0	28.8	57.6	.0042	20.0
4	29.5	4.0	25.5	51.0	.0031	20.0
8	27.0	4.2	22.8	45.6	.0022	20.5
24	24.2	4.6	19.6	39.2	.0013	18.5

Retained on Sieve Mesh No.	Size (mm)	Sample wt. (grams)	Cumulative wt. (grams)	Cumulative wt. (per cent)
230	.063	0.12	0.12	0.24

Percentage Sand	0.2
Percentage Silt	56.8
*Percentage Clay	43.0
Textural Designation	Silty Clay

*less than 2 microns

Sample No. T.H. 67-1 Unit F
0'-5' Below surface
Sample Wt. 50 g.

Time elapsed	Hydrometer reading (A)	Composite correction (B)	Corrected reading (C=A-B)	Percentage remaining in suspension	Diameter in mm	Temp. °C
15 sec.	39.0	5.0	34.0	68.0	.089	20.0
30	34.0	5.0	29.0	58.0	.065	20.0
1	29.3	5.0	24.3	48.6	.048	20.0
2	24.7	5.0	19.7	39.4	.035	20.0
4	21.1	5.0	16.1	32.2	.025	20.0
8	18.4	5.0	13.4	26.8	.018	20.0
15	17.0	5.0	12.0	24.0	.013	20.0
30	16.1	5.0	11.1	22.2	.0095	20.3
1 hr.	15.0	4.9	10.1	20.2	.00675	20.4
2	14.8	4.9	9.9	19.8	.00475	20.5
4	14.7	5.0	9.7	19.4	.0034	20.4
8	14.3	5.2	9.1	18.2	.0024	20.2
24	13.8	5.1	8.7	17.4	.0014	19.7

Retained on Sieve Mesh No.	Size (mm)	Sample wt. (grams)	Cumulative wt. (grams)	Cumulative wt. (per cent)
60	.250	0.67	0.67	1.34
80	.177	2.55	3.22	6.44
120	.125	4.63	7.85	15.70
170	.088	5.47	13.32	26.64
230	.063	5.72	19.04	38.08
PAN		0.90	19.94	39.88

Other Data:
Sand Sample Wt. 20.06 g.

Percentage Sand	38.1
Percentage Silt	43.9
*Percentage Clay	18.0
Textural Designation	Loam

*less than 2 microns

Sample No. T. H. 67-2 Unit B
115'-116' Below surface
Sample Wt. 50 g.

Time elapsed	Hydrometer reading (A)	Composite correction (B)	Corrected reading (C=A-B)	Percentage remaining in suspension	Diameter in mm	Temp. °C
15 sec.	35	5.3	29.7	59.4	.092	20.0
30	32	5.3	26.7	53.4	.067	20.0
1 min.	29.5	5.3	24.2	48.4	.048	20.0
2	28.1	5.3	22.8	45.6	.034	20.0
4	28.4	5.5	22.9	45.8	.024	20.0
8	26.4	5.5	20.9	41.8	.0174	20.0
15	25.1	5.5	19.6	39.2	.013	20.0
30	24.0	5.5	18.5	37.0	.0091	20.0
1 hr.	22.6	5.5	17.1	34.2	.0065	20.0
2	21.8	5.9	15.9	31.8	.0046	20.5
4	20.0	5.1	14.9	29.8	.00325	20.5
8	19.1	5.0	14.1	28.2	.0023	21.0
24	18.4	5.6	12.8	25.6	.0014	18.5

Retained on Sieve Mesh No.	Size (mm)	Sample wt. (grams)	Cumulative wt. (grams)	Cumulative wt. (per cent)
35	.500	0.67	0.67	1.34
60	.250	4.41	5.08	10.16
80	.177	5.86	10.94	21.88
120	.125	7.04	17.98	35.96
170	.080	3.81	21.79	43.58
230	.063	2.18	23.97	47.94
PAN		0.19	24.16	48.32

Other Data:
Sand Sample Wt. 24.19 g.

Percentage Sand	47.9
Percentage Silt	24.1
*Percentage Clay	28.0
Textural Designation	Sandy Clay Loam

*less than 2 microns

Sample No. T.H. 67-2 Unit B
116'-120' Below surface
Sample Wt. 50 g.

Time elapsed	Hydrometer reading (A)	Composite correction (B)	Corrected reading (C=A-B)	Percentage remaining in suspension	Diameter in mm	Temp. °C
15 sec.	35.5	5.3	30.2	60.4	.092	20.0
30	32.0	5.3	26.7	53.4	.067	20.0
1 min.	30.0	5.3	24.7	49.4	.048	20.0
2	28.1	5.3	22.8	45.6	.034	20.0
4	28.3	5.3	23.0	46.0	.024	20.0
8	26.4	5.3	21.1	42.2	.017	20.0
15	25.8	5.5	20.3	40.6	.013	20.0
30	24.3	5.5	19.0	38.0	.0091	20.0
1 hr.	23.2	5.3	17.9	35.8	.0064	20.0
2	22.1	5.1	17.0	34.0	.0046	20.3
4	20.5	5.1	15.4	30.8	.0031	20.5
8	19.2	4.8	14.4	28.8	.0023	21.0
24	19.0	5.6	13.4	26.8	.0014	18.5

Retained on Sieve Mesh No.	Size (mm)	Sample wt. (grams)	Cumulative wt. (grams)	Cumulative wt. (per cent)
35	.500	0.90	0.90	1.80
60	.250	2.86	3.79	7.52
80	.177	4.02	7.78	15.56
120	.125	7.66	15.44	30.88
170	.080	5.50	20.94	41.88
230	.063	3.29	24.23	48.46
PAN		0.33	24.56	49.12

Other Data:
Sand Sample Wt. 24.66 g.

Percentage Sand	49.1
Percentage Silt	22.9
*Percentage Clay	28.0
Textural Designation	Sandy Clay Loam

*less than 2 microns

Sample No. T.H. 67-2 Unit D
74'-78' Below surface
Sample Wt. 50 g.

Time elapsed	Hydrometer reading (A)	Composite correction (B)	Corrected reading (C=A-B)	Percentage remaining in suspension	Diameter in mm	Temp. °C
15 sec.	30.0	5.1	24.9	49.8	.094	21.0
30	28.1	5.1	23.0	46.0	.067	21.0
1 min.	26.6	5.1	21.5	43.0	.047	21.0
2	25.1	5.1	20.0	40.0	.034	21.0
4	24.9	5.1	19.8	39.6	.024	21.0
8	23.1	5.0	18.1	36.2	.017	21.0
15	21.1	5.0	16.1	32.2	.013	21.0
30	18.2	4.5	13.7	27.4	.0092	21.0
1 hr.	16.2	5.0	11.2	22.4	.0066	21.0
2	15.7	5.3	10.4	20.8	.0047	21.0
4	14.0	5.0	9.0	18.0	.0033	21.5
8	13.0	5.0	8.0	16.0	.0025	22.0
24	12.2	5.2	7.0	14.0	.0014	20.5

Retained on Sieve Mesh No.	Size (mm)	Sample wt. (grams)	Cumulative wt. (grams)	Cumulative wt. (per cent)
35	.500	4.77	4.77	9.54
60	.250	6.91	11.68	23.36
80	.177	5.00	16.68	33.36
120	.125	4.01	20.69	41.38
170	.080	3.10	23.79	47.58
230	.063	1.96	25.75	51.50
PAN		0.07	25.82	51.64

Other Data:
Sand Sample Wt. 26.08 g.

Percentage Sand	51.5
Percentage Silt	33.5
*Percentage Clay	15.0
Textural Designation	Loam

*less than 2 microns

Sample No. T.H. 67-2 Unit E
15'-20' Below surface
Sample Wt. 50 g.

Time elapsed	Hydrometer reading (A)	Composite correction (B)	Corrected reading (C=A-B)	Percentage remaining in suspension	Diameter in mm	Temp. °C
15 sec.	25	5.1	19.9	39.8	.098	20.0
30	17	5.1	11.9	23.8	.073	20.0
1 min.	12.9	5.1	7.8	15.6	.053	20.0
2	12.1	5.1	7.0	14.0	.038	20.0
4	12.8	5.1	7.7	15.4	.027	20.0
8	12.2	5.1	7.1	14.2	.019	20.0
15	12.0	5.1	6.9	13.8	.014	20.0
30	11.4	5.1	6.3	12.6	.0097	20.0
1 hr.	11.1	5.0	6.1	12.2	.0069	20.3
2	9.9	4.7	5.2	10.4	.0049	20.5
4	9.3	4.3	5.0	10.0	.0034	21.0
8	9.1	4.0	5.1	10.2	.0024	21.0
24	9.9	5.3	4.6	9.2	.0014	20.0

Retained on Sieve Mesh No.	Size (mm)	Sample wt. (grams)	Cumulative wt. (grams)	Cumulative wt. (per cent)
60	.250	0.18	0.18	.36
80	.177	0.49	0.67	1.34
120	.125	7.49	8.16	16.32
170	.088	21.83	29.99	59.98
230	.063	10.48	40.47	80.94
PAN		0.35	40.82	81.64

Other Data:
Sand Sample Wt. 40.84 g.

Percentage Sand	80.9
Percentage Silt	9.3
*Percentage Clay	9.8
Textural Designation	Loamy Sand

*less than 2 microns

Sample No. T. H. 67-2 Unit E
30'-37' Below surface
Sample Wt. 50 g.

Time elapsed	Hydrometer reading (A)	Composite correction (B)	Corrected reading (C=A-B)	Percentage remaining in suspension	Diameter in mm	Temp. °C
15 sec.	-	3.8	-	-	-	19.5
30	53.0	3.8	49.2	98.4	.057	19.5
1 min.	51.8	3.8	48.0	96.0	.040	19.5
2	49.6	3.8	45.8	91.6	.029	19.5
4	47.9	3.8	44.1	88.2	.021	19.5
8	44.9	3.8	41.1	82.2	.015	19.5
15	42.3	3.8	38.5	77.0	.011	19.5
30	39.4	3.8	35.6	71.2	.0081	19.8
1 hr.	36.4	4.2	32.2	64.4	.0059	20.0
2	32.7	4.6	28.1	56.2	.0043	20.2
4	28.8	4.2	24.6	49.2	.0031	20.5
8	25.0	4.1	20.9	41.8	.0022	21.0
24	22.0	4.4	17.6	35.2	.0013	19.5

Retained on Sieve Mesh No.	Size (mm)	Sample wt. (grams)	Cumulative wt. (grams)	Cumulative wt. (per cent)
170	.080	0.16	0.16	0.32
230	.063	0.26	0.42	0.84

Percentage Sand	0.8
Percentage Silt	59.4
*Percentage Clay	39.8
Textural Designation	Silty Clay Loam

*less than 2 microns

Sample No. T.H. 67-2 Unit E
64'-68' Below surface
Sample Wt. 50 g.

Time elapsed	Hydrometer reading (A)	Composite correction (B)	Corrected reading (C=A-B)	Percentage remaining in suspension	Diameter in mm	Temp. °C
15 sec.	-	3.8	-	-	-	19.7
30	54.1	3.8	50.3	100.6	.055	19.7
1 min.	53.1	3.8	49.3	98.6	.039	19.7
2	52.1	3.8	48.3	96.6	.028	19.7
4	51.0	3.8	47.2	94.4	.020	19.8
8	47.1	3.9	43.2	86.4	.015	19.8
15	43.2	3.9	39.3	78.6	.011	19.8
30	37.4	4.2	33.2	66.4	.0082	20.0
1 hr.	32.0	4.3	27.7	55.4	.0060	20.0
2	27.8	4.5	23.3	46.6	.0044	20.3
4	24.2	4.3	19.9	39.8	.0031	20.5
8	21.1	3.9	17.2	34.4	.0023	21.0
24	18.2	4.5	13.7	27.4	.0014	19.5

Retained on Sieve Mesh No.	Size (mm)	Sample wt. (grams)	Cumulative wt. (grams)	Cumulative wt. (per cent)
230	.063	-	0.05	0.10

Percentage Sand	0.1
Percentage Silt	67.6
*Percentage Clay	32.3
Textural Designation	Silty Clay Loam

*less than 2 microns

Sample No. T.H. 67-2 Unit F
0'-4' Below surface
Sample Wt. 50 g.

Time elapsed	Hydrometer reading (A)	Composite correction (B)	Corrected reading (C=A-B)	Percentage remaining in suspension	Diameter in mm	Temp. °C
15 sec.	36	5.1	30.9	61.8	.091	20.0
30	25	5.1	19.9	39.8	.070	20.0
1 min.	17.2	5.1	12.1	24.2	.052	20.0
2	15.4	5.1	10.3	20.6	.037	20.0
4	15.2	5.1	10.1	20.2	.026	20.0
8	1	5.1	--	-	-	20.0
15	14.2	5.1	9.1	18.2	.014	20.0
30	14.0	5.1	8.9	17.8	.0096	20.0
1 hr.	13.5	5.0	8.5	17.0	.0068	20.2
2	12.5	4.8	7.7	15.4	.0048	20.5
4	11.9	4.2	7.7	15.4	.0034	21.0
8	11.2	4.1	7.1	14.2	.0024	21.0
24	11.9	5.3	6.6	13.2	.0014	20.0

Retained on Sieve Mesh No.	Size (mm)	Sample wt. (grams)	Cumulative wt. (grams)	Cumulative wt. (per cent)
60	.250	0.05	0.05	0.10
80	.177	0.61	0.66	1.32
120	.125	6.49	7.15	14.30
170	.088	15.25	22.40	44.80
230	.063	12.91	35.31	70.62
PAN		0.93	36.24	72.48

Other Data:
Sand Sample Wt. 36.38 g.

Percentage Sand	70.6
Percentage Silt	14.6
*Percentage Clay	14.8
Textural Designation	Sandy Loam

*less than 2 microns

Sample No. T. H. 67-3 Unit B
79'-83' Below surface
Sample wt. 50 g.

Time elapsed	Hydrometer reading (A)	Composite correction (B)	Corrected reading (C=A-B)	Percentage remaining in suspension	Diameter in mm	Temp. °C
15 sec.	27.5	5.3	22.2	44.4	.097	20.0
30	26.7	5.3	21.4	42.8	.069	20.0
1 min.	25.3	5.3	20.0	40.0	.049	20.0
2	23.9	5.3	18.6	37.2	.035	20.0
4	22.9	5.3	17.6	35.2	.025	20.0
8	22.0	5.3	16.7	33.4	.018	20.0
15	21.0	5.3	15.7	31.4	.013	20.0
30	19.8	5.5	14.3	28.6	.0093	20.0
1 hr.	19.0	5.5	13.5	27.0	.0066	20.0
2	17.3	5.2	12.1	24.2	.0047	20.3
4	16.0	5.1	10.9	21.8	.0033	20.5
8	14.9	4.8	10.1	20.2	.0024	21.0
24	14.1	5.3	8.8	17.6	.0014	18.5

Retained on Sieve Mesh No.	Size (mm)	Sample wt. (grams)	Cumulative wt. (grams)	Cumulative wt. (per cent)
35	.500	5.57	5.57	11.14
60	.250	8.38	13.95	27.90
80	.177	6.22	20.17	40.34
120	.125	4.10	24.27	48.54
170	.080	2.30	26.57	53.14
230	.063	2.28	28.85	57.70
PAN		0.27	29.12	58.24

Other Data:
Sand Sample Wt. 29.17 g.

Percentage Sand	57.7
Percentage Silt	23.2
*Percentage Clay	19.1
Textural Designation	Sandy Loam

*less than 2 microns

Sample No. T.H. 67-3 Unit D
63'-64' Below surface
Sample Wt. 50 g.

Time elapsed	Hydrometer reading (A)	Composite correction (B)	Corrected reading (C=A-B)	Percentage remaining in suspension	Diameter in mm	Temp. °C
15 sec.	33.5	5.0	28.5	57.0	.092	21.0
30	30.9	5.0	25.9	51.8	.066	21.0
1 min.	28.2	5.0	23.2	46.4	.047	21.0
2	26.1	5.0	21.1	42.2	.034	21.0
4	25.5	5.0	20.5	41.0	.024	21.0
8	24.0	5.0	19.0	38.0	.017	21.0
15	22.9	4.8	18.1	36.2	.013	21.0
30	21.4	4.8	16.6	33.2	.0091	21.0
1 hr.	20.3	5.0	15.3	30.6	.0065	21.0
2	19.6	5.2	14.4	28.8	.0046	21.0
4	17.9	5.0	12.9	25.8	.0033	21.5
8	16.9	5.0	11.9	23.8	.0023	22.0
24	15.9	5.1	10.8	21.6	.0014	20.5

Retained on Sieve Mesh No.	Size (mm)	Sample wt. (grams)	Cumulative wt. (grams)	Cumulative wt. (per cent)
35	.500	4.99	4.99	9.98
60	.250	4.87	9.86	19.72
80	.177	3.43	13.29	26.58
120	.125	3.24	16.53	33.06
170	.080	3.43	19.96	39.92
230	.063	2.91	22.87	45.74
PAN		0.18	23.06	46.12

Other Data:
Sand Sample Wt. 23.22 g.

Percentage Sand	45.7
Percentage Silt	31.3
*Percentage Clay	23.0
Textural Designation	Loam

*less than 2 microns

Sample No. T.H. 67-3 Unit E
4'-8' Below surface
Sample Wt. 50 g.

Time elapsed	Hydrometer reading (A)	Composite correction (B)	Corrected reading (C=A-B)	Percentage remaining in suspension	Diameter in mm	Temp. °C
15 sec.	55.0	4.8	50.2	100.4	.078	20.0
30	54.0	4.8	49.2	98.4	.056	20.0
1 min.	53.1	4.8	48.3	96.6	.040	20.0
2	51.5	4.8	46.7	93.4	.028	20.0
4	50.0	4.8	45.2	90.4	.020	20.0
8	47.0	4.8	42.2	84.4	.015	20.0
15	43.3	4.8	38.5	77.0	.011	20.0
30	39.2	5.0	34.2	68.4	.0081	20.0
1 hr.	35.9	4.9	31.0	62.0	.0059	20.0
2	32.6	5.0	27.6	55.2	.0043	20.4
4	29.1	5.0	24.1	48.2	.0031	20.7
8	26.9	4.8	22.1	44.2	.0022	21.0
24	23.9	4.9	19.0	38.0	.0013	19.8

Retained on Sieve Mesh No.	Size (mm)	Sample wt. (grams)	Cumulative wt. (grams)	Cumulative wt. (per cent)
120	.177	0.12	0.12	0.24
170	.088	0.12	0.24	0.48
230	.063	0.16	0.40	0.80

Percentage Sand	0.8
Percentage Silt	46.7
*Percentage Clay	42.5
Textural Designation	Silty Clay

*less than 2 microns

Sample No. T. H. 67-3 Unit E
19'-20' Below surface
Sample Wt. 50 g.

Time elapsed	Hydrometer reading (A)	Composite correction (B)	Corrected reading (C=A-B)	Percentage remaining in suspension	Diameter in mm	Temp. °C
30 sec.	53.0	4.8	48.2	96.4	.056	20.0
1 min.	50.8	4.8	46.0	92.0	.040	20.0
2	47.1	4.8	42.3	94.6	.029	20.0
4	44.2	4.8	39.4	78.8	.021	20.0
8	40.0	5.0	35.0	70.0	.016	20.0
15	37.1	5.0	32.1	46.2	.012	20.0
30	32.1	4.9	27.2	54.4	.0086	20.0
1 hr.	28.4	4.0	24.4	48.8	.0062	20.0
2	24.8	5.0	19.8	39.6	.0045	20.4
4	22.0	5.0	17.0	34.0	.0033	20.7
8	19.2	4.8	14.4	28.8	.0023	21.0
24	16.9	4.9	12.0	24.0	.0014	19.7

Retained on Sieve Mesh No.	Size (mm)	Sample wt. (grams)	Cumulative wt. (grams)	Cumulative wt. (per cent)
120	.125	0.07	0.07	0.14
170	.088	0.07	0.14	0.28
230	.063	0.62	0.76	1.52

Percentage Sand	1.5
Percentage Silt	72.2
*Percentage Clay	26.3
Textural Designation	Silt Loam

*less than 2 microns

Sample No. T.H. 67-3 Unit E
28'-31' Below surface
Sample Wt. 50 g.

Time elapsed	Hydrometer reading (A)	Composite correction (B)	Corrected rreading (C=A-B)	Percentage remaining in suspension	Diameter in mm	Temp. °C
30 sec.	54.1	3.8	50.3	100.6	.055	19.5
1 min.	53.5	3.8	49.7	99.4	.039	19.5
2	52.3	3.8	48.5	97.0	.028	19.5
4	51.2	3.8	47.4	94.8	.020	19.5
8	48.9	3.8	45.1	90.2	.014	19.5
15	45.5	4.0	41.5	83.0	.011	19.6
30	40.5	3.9	36.6	73.2	.0080	19.8
1 hr.	34.1	4.2	29.9	59.8	.0059	20.0
2	27.9	4.5	23.4	46.8	.0044	20.2
4	23.0	4.3	18.7	37.4	.0032	20.5
8	19.1	3.9	15.2	30.4	.0023	21.0
24	16.8	4.5	12.3	24.6	.0014	19.5

Retained on Sieve Mesh No.	Size (mm)	Sample wt. (grams)	Cumulative wt. (grams)	Cumulative wt. (per cent)
230	.063	-	0.05	0.10

Percentage Sand	0.1
Percentage Silt	71.9
*Percentage Clay	28.0
Textural Designation	Silt Loam

*less than 2 microns

Sample No. T.H. 67-3 Unit E
44'-48' Below surface
Sample Wt. 50 g.

Time elapsed	Hydrometer reading (A)	Composite correction (B)	Corrected reading (C=A-B)	Percentage remaining in suspension	Diameter in mm	T Temp. °C
15 sec.	55.0	3.9	51.1	-	.077	19.8
30	54.7	3.9	50.8	-	.054	19.8
1 min.	53.9	3.9	50.0	100.0	.039	19.8
2	53.2	3.9	49.3	98.6	.028	19.8
4	53.0	3.9	49.1	98.2	.020	19.8
8	49.4	4.0	45.4	90.8	.014	20.0
15	43.3	4.0	39.3	78.6	.011	20.0
30	34.2	4.2	30.0	60.0	.0084	20.0
1 hr.	26.4	4.3	22.1	44.2	.0063	20.0
2	21.4	4.5	16.9	33.8	.0045	20.4
4	18.1	4.2	13.9	27.8	.0033	20.6
8	16.1	3.9	12.2	24.4	.0023	21.0
24	14.7	4.2	10.5	21.0	.0012	19.5

Retained on Sieve Mesh No.	Size (mm)	Sample wt. (grams)	Cumulative wt. (grams)	Cumulative wt. (per cent)
230	.063	-	0.06	0.12

Percentage Sand	0.1
Percentage Silt	76.4
*Percentage Clay	23.5
Textural Designation	Silt Loam

*less than 2 microns

Sample No. T.H. 67-4 Unit B
80' Below surface
Sample Wt. 50 g.

Time elapsed	Hydrometer reading (A)	Composite correction (B)	Corrected reading (C=A-B)	Percentage remaining in suspension	Diameter in mm	Temp. °C
15 sec.	30.0	5.5	24.5	49.0	.096	20.0
30	26.4	5.5	20.9	41.8	.069	20.0
1 min.	25.0	5.5	19.5	39.0	.049	20.0
2	23.6	5.5	18.1	36.2	.035	20.0
5	23.0	5.5	17.0	35.0	.025	20.0
8	22.1	5.5	16.6	33.2	.018	20.0
15	21.2	5.3	15.9	31.8	.013	20.0
30	20.2	5.3	14.9	29.8	.0092	20.0
1 hr.	19.0	5.2	13.8	27.6	.0065	20.3
2	18.2	4.8	13.4	26.8	.0046	20.3
4	17.6	5.0	12.6	25.2	.0033	20.5
8	16.7	5.0	11.7	23.4	.0023	21.0
24	16.2	5.6	10.6	21.2	.0014	18.5

Retained on Sieve Mesh No.	Size (mm)	Sample wt. (grams)	Cumulative wt. (grams)	Cumulative wt. (per cent)
35	.500	3.46	3.46	6.92
60	.250	8.17	11.63	23.26
80	.177	6.20	17.83	35.66
120	.125	6.25	24.08	48.16
170	.080	3.69	27.77	55.54
230	.063	2.38	30.15	60.30
PAN		0.22	30.37	60.74

Other Data:
Sand Sample Wt. 30.33 g.

Percentage Sand	60.3
Percentage Silt	17.2
*Percentage Clay	22.5
Textural Designation	Sandy Clay Loam

*less than 2 microns

Sample No. T.H. 67-4 Unit D
72' Below surface
Sample Wt. 50 g.

Time elapsed	Hydrometer reading (A)	Composite correction (B)	Corrected reading (C=A-B)	Percentage remaining in suspension	Diameter in mm	Temp. °C
15 sec.	36.0	5.0	31.0	62.0	.090	21.0
30	32.5	5.0	27.5	55.0	.065	21.0
1 min.	30.3	5.0	25.3	50.6	.047	21.0
2	28.5	5.0	23.5	47.0	.034	21.0
4	27.7	4.8	22.9	45.8	.024	21.0
8	25.8	4.8	21.0	42.0	.017	21.0
15	24.0	4.8	19.2	38.4	.013	21.0
30	22.1	5.0	17.1	34.2	.0089	21.0
1 hr.	20.4	5.0	15.4	30.8	.0065	21.0
2	18.5	5.2	13.3	26.6	.0046	21.5
4	16.3	4.9	11.4	22.8	.0033	21.5
8	15.4	5.0	10.4	20.8	.0023	22.0
24	14.6	5.1	9.5	18.0	.0014	20.5

Retained on Sieve Mesh No.	Size (mm)	Sample wt. (grams)	Cumulative wt. (grams)	Cumulative wt. (per cent)
35	.500	2.26	2.26	4.52
60	.250	5.05	7.31	14.62
80	.177	3.53	10.84	21.68
120	.125	4.09	14.93	29.86
170	.080	3.00	17.93	35.86
230	.063	2.77	20.70	41.40
PAN		0.25	20.95	41.90

Other Data:
Sand Sample Wt. 20.96 g.

Percentage Sand	41.4
Percentage Silt	39.1
*Percentage Clay	19.5
Textural Designation	Loam

*less than 2 microns

Sample No. T.H. 67-4 Unit E
25' Below surface
Sample Wt. 50 g.

Time elapsed	Hydrometer reading (A)	Composite correction (B)	Corrected reading (C=A-B)	Percentage remaining in suspension	Diameter in mm	Temp. °C
30 sec.	33.0	5.0	28.0	56.0	.066	20.0
1 min.	24.5	5.0	19.5	39.0	.049	20.0
2	20.2	5.0	15.2	30.4	.036	20.0
4	19.3	5.0	14.3	28.6	.025	20.0
8	17.5	5.0	12.5	25.0	.018	20.0
15	16.5	5.0	11.5	23.0	.013	20.0
30	15.5	5.0	10.5	21.0	.0095	20.0
1 hr.	15.0	5.0	10.0	20.0	.0068	20.3
2	13.2	5.0	8.2	16.4	.0048	20.4
4	13.1	5.0	8.1	16.2	.0034	20.7
8	12.4	4.7	7.7	15.4	.0024	21.1
24	11.9	4.9	7.0	14.0	.0014	20.0

Retained on Sieve Mesh No.	Size (mm)	Sample wt. (grams)	Cumulative wt. (grams)	Cumulative wt. (per cent)
60	.250	0.17	0.17	0.34
80	.177	0.17	0.34	0.68
120	.125	1.43	1.77	3.54
170	.088	7.11	8.99	17.98
230	.063	12.65	21.64	43.28
PAN		1.20	22.74	45.48

Other Data:
Sand Sample Wt. 22.77 g.

Percentage Sand	43.3
Percentage Silt	42.2
*Percentage Clay	14.5
Textural Designation	Loam

*less than 2 microns

Sample No. T.H. 67-4 Unit E
48' Below surface
Sample Wt. 50 g.

Time elapsed	Hydrometer reading (A)	Composite correction (B)	Corrected reading (C=A-B)	Percentage remaining in suspension	Diameter in mm	Temp. °C
30 sec.	54.1	4.2	49.9	99.8	.055	20.0
1 min.	52.8	4.2	48.6	97.2	.039	20.0
2	49.0	4.2	44.8	89.6	.029	20.0
4	42.9	4.2	38.7	77.4	.022	20.0
8	35.3	4.2	31.1	62.2	.016	20.0
15	29.6	4.2	25.4	50.8	.012	20.0
30	24.9	4.2	20.7	41.4	.0089	20.0
1 hr.	22.3	4.3	18.0	36.0	.0064	20.1
2	19.5	4.2	15.3	30.6	.0048	20.4
4	18.3	4.3	14.0	28.0	.0033	20.6
24	16.3	4.2	12.1	24.2	.0014	19.5

Retained on Sieve Mesh No.	Size (mm)	Sample wt. (grams)	Cumulative wt. (grams)	Cumulative wt. (per cent)
230	.063		0.14	0.28

Other Data:
Sand fraction - very fine coal

Percentage Sand	0.3
Percentage Silt	74.7
*Percentage Clay	25.0
Textural Designation	Silt Loam

*less than 2 microns

Sample No. T.H. 67-4 Unit E
64' Below surface
Sample Wt. 50 g.

Time elapsed	Hydrometer reading (A)	Composite correction (B)	Corrected reading (C=A-B)	Percentage remaining in suspension	Diameter in mm	Temp. °C
15 sec.	51	3.2	47.8	95.6	.076	23.5
30	50.3	3.2	47.1	94.2	.054	23.5
1 min.	49.4	3.2	46.2	92.4	.039	23.5
2	48.7	3.2	45.5	91.0	.027	23.5
4	48.4	3.2	45.2	90.4	.020	23.5
8	45.8	3.2	42.6	85.2	.014	23.5
15	40.5	3.2	37.3	74.6	.011	23.5
30	32.3	3.4	28.9	57.8	.0081	23.5
1 hr.	25.6	3.4	22.2	44.4	.0060	23.5
2	20.3	3.3	17.0	34.0	.0044	23.7
4	17.9	3.7	14.2	28.4	.0032	23.0
8	16.0	3.7	12.2	24.4	.0023	23.6
24	15.3	5.0	10.3	20.6	.0014	20.2

Retained on Sieve Mesh No.	Size (mm)	Sample wt. (grams)	Cumulative wt. (grams)	Cumulative wt. (per cent)
35	.500	0.37	0.37	0.74
60	.250	0.75	1.12	2.24
80	.177	0.50	1.62	3.24
120	.125	0.61	2.23	4.46
170	.088	0.50	2.73	5.46
230	.063	0.55	3.28	6.56
PAN		0.01	3.29	6.58

Other Data:
Sand Sample Wt. 3.35 g.

Percentage Sand	6.6
Percentage Silt	69.9
*Percentage Clay	23.5
Textural Designation	Silt Loam

*less than 2 microns

Sample No. T.H. 67-4 Unit F
0'-5' Below surface
Sample Wt. 50 g.

Time elapsed	Hydrometer reading (A)	Composite correction (B)	Corrected reading (C=A-B)	Percentage remaining in suspension	Diameter in mm	Temp. °C
30 sec.	23.5	5.0	18.5	37.0	.070	20.0
1 min.	18.0	5.0	13.0	26.0	.051	20.0
2	16.6	5.0	11.6	23.2	.037	20.0
4	16.8	5.0	13.8	27.6	.026	20.0
8	16.3	5.0	11.3	22.6	.018	20.0
15	16.1	4.9	11.2	22.4	.013	20.0
30	15.8	4.9	10.9	21.8	.0095	20.0
1 hr.	15.2	5.0	10.2	20.4	.0067	20.0
2	14.7	5.0	9.7	19.4	.0048	20.4
4	14.3	5.0	9.3	18.6	.0034	20.7
8	13.9	4.8	9.1	18.2	.0024	21.0
24	13.2	4.9	8.3	16.6	.0014	20.0

Retained on Sieve Mesh No.	Size (mm)	Sample wt. (grams)	Cumulative wt. (grams)	Cumulative wt. (percent)
60	.250	0.17	0.17	0.34
80	.177	1.31	1.48	2.96
120	.125	5.99	7.47	14.94
170	.088	16.27	23.74	47.48
230	.063	12.00	35.74	71.48
PAN		0.57	36.31	72.62

Other Data:
Sand Sample Wt. 36.31

Percentage Sand	71.5
Percentage Silt	11.0
*Percentage Clay	17.5
Textural Designation	Sandy Loam

*less than 2 microns

Sample No. T.H. 67-5 Unit B
114'-118' Below surface
Sample Wt. 50 g.

Time elapsed	Hydrometer reading (A)	Composite correction (B)	Corrected reading (C=A-B)	Percentage remaining in suspension	Diameter in mm	Temp. °C
15 sec.	33	5.5	27.5	55.0	.094	20.0
30	31.2	5.5	25.7	51.4	.067	20.0
1 min.	29.1	5.5	23.6	47.2	.048	20.0
2	27.6	5.3	22.3	44.6	.034	20.0
4	2	-	-	-	-	20.0
8	25.2	5.3	19.9	39.8	.017	20.0
15	24.2	5.3	18.9	37.8	.013	20.0
30	23.0	5.3	17.7	35.4	.0091	20.0
1 hr.	22.0	5.2	16.8	33.6	.0064	20.3
2	20.5	5.6	14.9	29.8	.0045	20.5
4	19.5	4.8	14.7	29.4	.0033	20.5
8	17.6	4.9	12.7	25.4	.0023	21.0
24	16.8	5.6	11.2	22.4	.0014	18.5

Retained on Sieve Mesh No.	Size (mm)	Sample wt. (grams)	Cumulative wt. (grams)	Cumulative wt. (per cent)
35	.500	3.79	3.79	7.58
60	.250	5.70	9.49	18.98
80	.177	4.02	13.51	27.02
120	.125	3.21	16.72	33.44
170	.080	3.13	19.85	39.70
230	.063	2.27	22.12	44.24
PAN		.02	22.14	44.28

Other Data:
Sand Sample Wt. 22.22 g.

Percentage Sand	44.2
Percentage Silt	31.3
*Percentage Clay	24.5
Textural Designation	Loam

*less than 2 microns

Sample No. T.H. 67-5 Unit C
84'-88' Below surface
Sample Wt. 50 g.

Time elapsed	Hydrometer reading (A)	Composite correction (B)	Corrected reading (C=A-B)	Percentage remaining in suspension	Diameter in mm	Temp. °C
15 sec.	17.5	4.8	12.7	25.4	.100	21.0
30	13.5	4.8	8.7	17.4	.073	21.0
1 min.	11.4	4.8	6.6	13.2	.053	21.0
2	10.0	4.8	5.2	10.4	.037	21.0
4	9.3	4.8	4.5	9.0	.027	21.0
8	9.0	4.8	4.2	8.4	.019	21.0
15	8.8	5.0	3.8	7.6	.014	21.0
30	7.9?	5.0	2.9	5.8	.0098	21.0
1 hr.	8.0	5.3	2.7	5.4	.0069	21.0
2	7.2	5.2	2.0	4.0	.0049	21.5
4	6.9	4.8	2.1	4.2	.0035	21.5
8	6.7	5.0	1.7	3.4	.0024	22.0
24	6.6	5.1	1.5	3.0	.0014	20.5

Retained on Sieve Mesh No.	Size (mm)	Sample wt. (grams)	Cumulative wt. (grams)	Cumulative wt. (per cent)
35	.500	0.81	0.81	1.62
60	.250	7.08	7.89	15.78
80	.177	16.57	24.46	48.92
120	.125	7.45	31.91	63.82
170	.080	5.20	37.11	74.22
230	.063	3.24	40.35	80.70
PAN		0.11	40.46	80.92

Other Data:
Sand Sample Wt. 40.47 g.

Sample No. T.H. 67-5 Unit E
54' Below surface
Sample Wt. 50 g.

Time elapsed	Hydrometer reading (A)	Composite correction (B)	Corrected reading (C=A-B)	Percentage remaining in suspension	Diameter in mm	Temp. °C
15 sec.	55.0	4.2	50.8	-	.077	20.0
30	54.2	4.2	50.0	100	.055	20.0
1 min.	53.9	4.2	49.7	79.4	.039	20.0
2	53.3	4.2	49.1	98.2	.028	20.0
4	53.0	4.2	48.8	97.6	.020	20.0
8	51.0	4.2	46.8	93.6	.014	20.0
15	46.8	4.3	42.5	85.0	.011	20.0
30	38.4	4.3	34.1	68.2	.0082	20.1
1 hr.	30.3	4.6	25.7	51.4	.0061	20.2
2	23.8	4.2	19.6	39.2	.0044	21.5
4	19.5	4.1	15.4	30.6	.0032	20.6
8	17.1	3.9	13.2	26.4	.0023	21.0
24	15.3	4.8	10.5	21.0	.0014	20.0

Retained on Sieve Mesh No.	Size (mm)	Sample wt. (grams)	Cumulative wt. (grams)	Cumulative wt. (per cent)
230	.063		0.17	0.34

Percentage Sand	0.3
Percentage Silt	74.7
*Percentage Clay	25.0
Textural Designation	Silt Loam

*less than 2 microns

Sample No. T.H. 67-5 Unit E
60' Below surface
Sample Wt. 50 g.

Time elapsed	Hydrometer reading (A)	Composite correction (B)	Corrected reading (C=A-B)	Percentage remaining in suspension	Diameter in mm	Temp. °C
15 sec.	54	3.2	50.8	-	.073	23.5
30	53.5	3.2	50.3	-	.052	23.5
1 min.	53.1	3.2	49.9	99.8	.037	23.5
2	52.9?	3.2	49.7	99.4	.026	23.5
4	52.7?	3.2	49.5	99.0	.019	23.5
8	50.9	3.2	47.7	95.4	.013	23.5
15	47.9	3.4	44.5	89.0	.010	23.5
30	41.9	-	-	-	-	23.5
1 hr.	37.5	3.4	34.1	68.2	.0055	23.5
2	33.3	3.6	29.7	59.4	.0040	23.7
4	29.5	3.8	25.7	51.4	.0030	23.0
8	26.3	3.8	22.5	45.0	.0021	23.5
24	24.2	5.0	19.2	38.4	.0013	20.3

Retained on Sieve Mesh No.	Size (mm)	Sample wt. (grams)	Cumulative wt. (grams)	Cumulative wt. (per cent)
230	.063	.03		.06

Percentage Sand	0.1
Percentage Silt	56.0
*Percentage Clay	43.9
Textural Designation	Silty Clay

*less than 2 microns

Sample No. T.H. 67-6 Unit B
94' Below surface
Sample Wt. 50 g.

Time elapsed	Hydrometer reading (A)	Composite correction (B)	Corrected reading (C=A-B)	Percentage remaining in suspension	Diameter in mm	Temp. °C
15 sec.	34.5	5.3	29.2	58.4	.093	20.0
30	30.5	5.3	25.2	50.4	.067	20.0
1 min.	27.8	5.3	22.5	45.0	.048	20.0
2	25.8	5.3	20.5	41.0	.035	20.0
4	25.0	5.3	19.7	39.4	.025	20.0
8	24.1	5.3	18.8	37.6	.018	20.0
15	23.1	5.3	17.8	35.6	.013	20.0
30	21.3	5.3	16.0	32.0	.0092	20.0
1 hr.	20.1	5.2	14.9	29.8	.0065	20.3
2	18.9	5.6	13.3	26.6	.0046	20.5
4	17.2	4.8	12.4	24.8	.0033	20.5
8	16.2	4.9	11.3	22.6	.0023	21.0
24	15.2	5.5	9.7	19.4	.0014	18.5

Retained on Sieve Mesh No.	Size (mm)	Sample wt. (grams)	Cumulative wt. (grams)	Cumulative wt. (per cent)
35	.500	2.03	2.03	4.06
60	.250	4.60	6.63	13.26
80	.177	3.53	10.16	20.32
120	.125	4.33	14.49	28.98
170	.080	3.62	18.11	36.22
230	.063	3.54	21.65	43.30
PAN		0.50	22.15	44.30

Other Data:
Sand Sample Wt. 22.22 g.

Percentage Sand	43.3
Percentage Silt	35.1
*Percentage Clay	21.6
Textural Designation	Loam

*less than 2 microns

Sample No. T.H. 67-6 Unit E
27' Below surface
Sample Wt. 50 g.

Time elapsed	Hydrometer reading (A)	Composite correction (B)	Corrected reading (C=A-B)	Percentage remaining in suspension	Diameter in mm	Temp. °C
15 sec.	54	4.8	49.2	98.4	.079	20.0
30	53.2	4.8	48.4	96.8	.056	20.0
1 min.	52.1	4.8	47.3	94.6	.040	20.0
2	51.4	4.8	46.6	93.2	.028	20.0
4	49.9	4.8	45.1	90.2	.020	20.0
8	47.9	4.8	43.1	86.2	.015	20.0
15	45.7	5.0	40.7	81.4	.011	20.0
30	43.1	5.0	38.1	76.2	.0079	20.3
1 hr.	40.4	5.0	35.4	70.8	.0057	20.4
2	38.4	5.0	33.4	66.8	.0041	20.4
4	36.1	5.0	31.1	62.2	.0030	20.7
8	32.7	4.7	28.0	56.0	.0021	21.1
24	29.1	4.7	24.4	48.8	.0013	20.0

Retained on Sieve Mesh No.	Size (mm)	Sample wt. (grams)	Cumulative wt. (grams)	Cumulative wt. (per cent)
120	.125	.03	.03	.06
170	.088	.14	.17	.34
230	.063	.55	.72	1.44

Percentage Sand	0.1
Percentage Silt	44.9
*Percentage Clay	55.0
Textural Designation	Silty Clay

*less than 2 microns

Sample No. T.H. 67-6 Unit E
42' Below surface
Sample Wt. 50 g.

Time elapsed	Hydrometer reading (A)	Composite correction (B)	Corrected reading (C=A-B)	Percentage remaining in suspension	Diameter in mm	Temp. °C
1 min.	53.2	3.4	49.8	99.6	.037	23.5
2	52.8	3.4	49.4	98.8	.026	23.5
4	-	3.4	-	-	-	23.5
8	51.8	3.4	48.4	96.8	.013	23.5
15	49.5	3.4	46.1	92.2	.010	23.5
30	45.7	3.4	42.3	84.6	.0073	23.5
1 hr.	41.9	3.3	38.6	77.2	.0053	23.7
2	39.6	3.6	36.0	72.0	.0038	23.5
4	37.0	3.8	33.2	66.4	.0028	22.8
8	34.1	3.9	30.2	60.4	.0020	23.5
24	31.9	5.0	26.9	53.8	.0012	20.5

Retained on Sieve Mesh No.	Size (mm)	Sample wt. (grams)	Cumulative wt. (grams)	Cumulative wt. (per cent)
170	.080	.13	.13	.26
230	.063	.08	.21	.42

Percentage Sand	0.4
Percentage Silt	39.1
*Percentage Clay	60.5
Textural Designation	Heavy Clay

*less than 2 microns

Sample No. T.H. 67-6 Unit E
50' Below surface
Sample Wt. 50 g.

Time elapsed	Hydrometer reading (A)	Composite correction (B)	Corrected reading (C=A-B)	Percentage remaining in suspension	Diameter in mm	Temp. °C
15 sec.	-	3.2	-	-	-	23.5
30	53.2	3.2	50.0	-	.053	23.5
1 min.	53.1	3.2	49.9	99.8	.037	23.5
2	52.9	3.2	49.7	99.4	.026	23.5
4	52.9	3.3	49.6	99.2	.019	23.5
8	52.7	3.4	49.3	98.6	.013	23.5
15	51.2	3.4	47.8	95.6	.0098	23.5
30	48.9	3.4	45.5	91.0	.0071	23.5
1 hr.	46.1	3.4	42.7	85.4	.0051	23.5
2	43.1	3.6	39.5	79.0	.0037	23.6
4	39.5	3.8	35.7	71.4	.0028	22.7
8	36.1	3.9	32.2	64.4	.0019	23.5
24	33.3	5.0	28.3	56.6	.0012	20.4

Retained on Sieve Mesh No.	Size (mm)	Sample wt. (grams)	Cumulative wt. (grams)	Cumulative wt. (per cent)
230	.063	.01	.01	.02

Percentage Sand	0.0
Percentage Silt	34.8
*Percentage Clay	65.2
Textural Designation	Heavy Clay

*less than 2 microns

Sample No. T.H. 67-6 Unit E
55' Below surface
Sample Wt. 50 g.

Time elapsed	Hydrometer reading (A)	Composite correction (B)	Corrected reading (C=A-B)	Percentage remaining in suspension	Diameter in mm	Temp. °C
15 sec.	45.0	5.0	40.0	80.0	.084	21.0
30	43.8	5.0	38.8	77.6	.060	21.0
1 min.	42.5	5.0	37.5	75.0	.043	21.0
2	41.3	5.0	36.3	72.6	.031	21.0
4	41.1	5.0	36.1	72.2	.022	21.0
8	39.1	5.0	34.1	68.2	.016	21.0
15	35.1	5.0	30.1	60.2	.012	21.0
30	28.9	5.2	23.7	47.4	.0087	21.0
1 hr.	22.7	5.3	17.4	34.8	.0064	21.0
2	19.0	5.0	14.0	28.0	.0046	21.5
4	16.2	4.6	11.6	23.2	.0033	21.7
8	15.0	5.0	10.0	20.0	.0023	22.0
24	13.1	5.1	8.0	16.0	.0014	20.6

Retained on Sieve Mesh No.	Size (mm)	Sample wt. (grams)	Cumulative wt. (grams)	Cumulative wt. (per cent)
35	.500	1.19	1.19	2.38
60	.250	2.17	3.36	6.72
80	.177	1.80	5.16	10.32
120	.125	2.07	7.23	14.46
170	.080	1.35	8.58	17.16
230	.063	1.09	9.67	19.34
PAN		0.05	9.72	19.44

Other Data:
Sand Sample Wt. 9.72 g.

Percentage Sand	19.3
Percentage Silt	62.3
*Percentage Clay	18.4
Textural Designation	Silt Loam (Lacustrine Till?)

*less than 2 microns

Sample No. T.H. 67-6 Unit E
60'-64' Below surface
Sample Wt. 50 g.

Time elapsed	Hydrometer reading (A)	Composite correction (B)	Corrected reading (C=A-B)	Percentage remaining in suspension	Diameter in mm	Temp. °C
30 sec.	45.5	3.4	42.1	84.2	.057	23.5
1 min.	39.3	3.4	35.9	71.8	.042	23.5
2	31.2	3.4	27.8	55.6	.032	23.5
4	26.0	3.4	22.6	45.2	.023	23.5
8	22.3	3.4	18.9	37.8	.017	23.5
15	20.0	3.4	16.6	33.2	.012	23.5
30	18.1	3.4	14.7	29.4	.0089	23.5
1 hr.	15.9	3.3	12.6	25.2	.0063	23.7
2	14.9	3.6	11.3	22.6	.0045	23.5
4	13.9	3.8	10.1	20.2	.0033	22.9
8	13.3	4.0	9.3	18.6	.0023	23.4
24	13.0	4.9	8.1	16.2	.0013	23.5

Retained on Sieve Mesh No.	Size (mm)	Sample wt. (grams)	Cumulative wt. (grams)	Cumulative wt. (per cent)
60	.250	0.00	0.00	0.00
80	.177	0.03	0.03	0.06
120	.125	0.37	0.40	0.80
170	.088	0.80	1.20	2.40
230	.063	3.19	4.39	8.78
PAN		0.90	5.29	10.58

Other Data:
Sand Sample Wt. 5.39 g.

Percentage Sand	8.8
Percentage Silt	73.4
*Percentage Clay	17.8
Textural Designation	Silt Loam

*less than 2 microns

Sample No. T.H. 67-6 Unit F
0'-5' Below surface
Sample Wt. 50 g.

Time elapsed	Hydrometer reading (A)	Composite correction (B)	Corrected reading (C=A-B)	Percentage remaining in suspension	Diameter in mm	Temp. °C
15 sec.	27	5.0	22.0	44.0	.097	20.0
30	22.5	5.0	17.5	35.0	.071	20.0
1 min.	19.0	5.0	14.0	28.0	.051	20.0
2	17.0	5.0	12.0	24.0	.036	20.0
4	17.4	5.0	12.4	24.8	.026	20.0
8	16.9	5.0	11.9	23.8	.018	20.0
15	16.1	5.0	11.1	22.2	.013	20.0
30	15.1	5.0	10.1	20.2	.0096	20.0
1 hr.	14.4	5.0	9.4	18.8	.0067	20.3
2	14.0	5.0	9.0	18.0	.0048	20.4
4	13.6	5.0	8.6	17.2	.0034	20.7
8	12.6	4.7	7.9	15.8	.0024	21.1
24	12.1	4.8	7.3	14.6	.0014	20.0

Retained on Sieve Mesh No.	Size (mm)	Sample wt. (grams)	Cumulative wt. (grams)	Cumulative wt. (per cent)
60	.250	5.56	5.56	11.12
80	.177	6.62	12.18	24.36
120	.125	7.47	19.65	39.30
170	.088	5.65	25.30	50.60
230	.063	7.30	32.60	65.20
PAN		1.91	34.51	69.02

Other Data:
Sand Sample Wt. 34.55 g.

Percentage Sand	65.2
Percentage Silt	19.8
*Percentage Clay	15.0
Textural Designation	Sandy Loam

*less than 2 microns

Sample No. T.H. 67-7 Unit C
111'-113' Below surface
Sample Wt. 50 g.

Time elapsed	Hydrometer reading (A)	Composite correction (B)	Corrected reading (C=A-B)	Percentage remaining in suspension	Diameter in mm	Temp. °C
15 sec.	38	5.3	32.7	65.4	.090	20.0
30	36.5	5.3	31.2	62.4	.065	20.0
1 min.	35.3	5.3	30.0	60.0	.046	20.0
2	34.0	5.3	28.7	57.4	.033	20.0
4	33.4	5.3	28.1	56.2	.023	20.0
8	30.0	5.3	24.7	49.4	.017	20.0
15	26.4	5.3	21.1	42.2	.013	20.3
30	22.4	5.2	17.2	34.4	.0091	20.3
1 hr.	19.9	5.9	14.0	28.0	.0065	20.5
2	16.3	5.0	11.3	22.6	.0047	20.5
4	13.8	4.9	8.9	17.8	.0034	20.5
8	11.9	4.9	7.0	14.0	.0024	21.0
24	11.1	5.3	5.8	11.6	.0014	18.7

Retained on Sieve Mesh No.	Size (mm)	Sample wt. (grams)	Cumulative wt. (grams)	Cumulative wt. (per cent)
18	1.000	4.72	4.72	9.44
35	0.500	4.13	8.85	17.70
60	0.250	3.21	12.06	24.12
120	0.125	2.39	14.45	28.90
170	0.080	1.12	15.57	31.14
230	0.063	0.72	16.29	32.58
PAN		0.05	16.34	32.68

Other Data:
Sand Sample Wt. 16.48 g.

Percentage Sand	32.6
Percentage Silt	54.4
*Percentage Clay	13.0
Textural Designation	Silt Loam

*less than 2 microns

Sample No. T.H. 67-7 Unit D
100' Below surface
Sample Wt. 50 g.

Time elapsed	Hydrometer reading (A)	Composite correction (B)	Corrected reading (C=A-B)	Percentage remaining in suspension	Diameter in mm	Temp. °C
15 sec.	37	5.0	32.0	64.0	.090	21.0
30	33	5.0	28.0	56.0	.065	21.0
1 min.	30.5	5.0	25.5	51.0	.047	21.0
2	28.5	5.0	23.5	47.0	.034	21.0
4	28.0	5.0	23.0	46.0	.024	21.0
8	25.5	5.0	20.5	41.0	.017	21.0
15	23.9	5.0	18.9	37.8	.012	21.0
30	22.1	5.3	16.8	33.6	.0090	21.0
1 hr.	20.1	5.3	14.8	29.6	.0065	21.0
2	18.1	5.1	13.0	26.0	.0046	21.5
4	16.7	4.6	12.1	24.2	.0033	21.7
8	15.7	5.0	10.7	21.4	.0023	22.0
24	14.6	5.1	9.5	19.0	.0014	20.6

Retained on Sieve Mesh No.	Size (mm)	Sample wt. (grams)	Cumulative wt. (grams)	Cumulative wt. (per cent)
35	.500	3.48	3.48	6.96
60	.250	5.59	0.07	18.14
80	.177	3.65	12.72	25.44
120	.125	3.19	15.91	31.82
170	.080	3.29	19.20	38.40
230	.063	2.79	21.99	43.98
PAN		0.13	22.12	44.24

Other Data:
Sand Sample Wt. 22.13 g.

Percentage Sand	44.0
Percentage Silt	36.0
*Percentage Clay	20.0
Textural Designation	Loam

*less than 2 microns

Sample No. T.H. 67-7 Unit E
18' Below surface
Sample Wt. 50 g.

Time elapsed	Hydrometer reading (A)	Composite correction (B)	Corrected reading (C=A-B)	Percentage remaining in suspension	Diameter in mm	Temp. °C
15 sec.	38	5.1	32.9	65.8	.090	20.0
30	32	5.1	26.9	53.8	.066	20.0
1 min.	26	5.1	20.9	41.8	.049	20.0
2	23	5.1	17.9	35.8	.035	20.0
4	23	5.1	17.9	35.8	.025	20.0
8	21.8	5.1	16.7	33.4	.018	20.0
15	20.0	5.0	15.0	30.0	.013	20.2
30	18.5	5.0	13.5	27.0	.0093	20.2
1 hr.	17.1	5.0	12.1	24.2	.0066	20.5
2	15.3	4.8	10.5	21.0	.0047	20.6
4	14.4	4.3	10.1	20.2	.0033	21.0
8	13.7	4.2	9.5	19.0	.0024	21.0
24	13.8	5.3	8.5	17.0	.0014	20.0

Retained on Sieve Mesh No.	Size (mm)	Sample wt. (grams)	Cumulative wt. (grams)	Cumulative wt. (per cent)
60	.250	0.41	0.41	.82
80	.177	1.68	2.09	4.18
120	.125	4.20	6.29	12.58
170	.088	7.95	14.24	28.48
230	.063	9.65	23.89	47.78
PAN		0.65	24.54	49.08

Other Data:
Sand Sample Wt. 24.40 g.

Percentage Sand	47.8
Percentage Silt	34.2
*Percentage Clay	18.0
Textural Designation	Loam

*less than 2 microns

Sample No. T.H. 67-7 Unit E
89' Below surface
Sample Wt. 50 g.

Time elapsed	Hydrometer reading (A)	Composite correction (B)	Corrected reading (C=A-B)	Percentage remaining in suspension	Diameter in mm	Temp. °C
30 sec.	52.3	3.4	48.9	97.8	.053	23.5
1 min.	51.8	3.4	48.4	96.8	.038	23.5
2	51.0	3.4	47.6	95.2	.027	23.5
4	50.8	3.4	47.4	94.8	.019	23.5
8	47.2	3.4	43.8	87.6	.014	23.5
15	41.7	3.4	38.3	76.6	.011	23.5
30	33.8	3.3	30.5	61.0	.0080	23.7
1 hr.	27.8	3.3	24.5	49.0	.0059	23.7
2	22.7	3.6	19.1	38.2	.0043	23.5
4	19.1	3.7	15.4	30.8	.0032	23.0
8	17.3	4.0	13.3	26.6	.0023	23.0
24	16.1	4.8	11.3	22.6	.0010	23.5

Retained on Sieve Mesh No.	Size (mm)	Sample wt. (grams)	Cumulative wt. (grams)	Cumulative wt. (per cent)
35	.500	.09	.09	.18
60	.250	.14	.23	.46
120	.125	.15	.38	.76
170	.080	.08	.46	.92
230	.063	.11	.57	1.14

Percentage Sand	1.1
Percentage Silt	73.7
*Percentage Clay	25.2
Textural Designation	Silt Loam

*less than 2 microns

Sample No. T.H. 67-7 Unit F
0'-5' Below surface
Sample Wt. 50 g.

Time elapsed	Hydrometer reading (A)	Composite correction (B)	Corrected reading (C=A-B)	Percentage remaining in suspension	Diameter in mm	Temp. °C
15 sec.	26.5	5.1	21.4	42.8	.098	20.0
30	18.0	5.1	12.9	25.8	.073	20.0
1 min.	14.3	5.1	9.2	18.4	.052	20.0
2	13.7	5.1	8.6	17.2	.037	20.0
4	14.0	5.1	8.9	17.8	.026	20.0
8	13.9	5.1	8.8	17.6	.019	20.0
15	13.7	5.1	8.6	17.2	.014	20.0
30	12.9	5.0	7.9	15.8	.0096	20.2
1 hr.	12.1	5.0	7.1	14.2	.0058	20.4
2	11.1	4.7	6.4	12.8	.0048	20.5
4	10.7	4.3	6.4	12.8	.0034	21.0
8	10.3	4.2	6.1	12.2	.0026	21.0
24	10.9	5.3	5.6	11.2	.0014	20.0

Retained on Sieve Mesh No.	Size (mm)	Sample wt. (grams)	Cumulative wt. (grams)	Cumulative wt. (per cent)
60	.250	0.25	0.25	.50
80	.177	1.81	2.06	4.12
120	.125	7.60	9.66	19.32
170	.088	16.77	26.43	52.86
230	.063	9.10	35.53	71.06
PAN		0.29	35.82	71.64

Other Data:
Sand Sample Wt. 35.81 g.

Percentage Sand	71.1
Percentage Silt	17.4
*Percentage Clay	11.5
Textural Designation	Sandy Loam

*less than 2 microns

Sample No. T.H. 67-8 Unit B
135'-141' Below surface
Sample Wt. 50 g.

Time elapsed	Hydrometer reading (A)	Composite correction (B)	Corrected reading (C=A-B)	Percentage remaining in suspension	Diameter in mm	Temp. °C
15 sec.	35.5	5.3	30.2	60.4	.091	20.3
30	31.7	5.3	26.4	52.8	.066	20.3
1 min.	29.3	5.3	24.0	48.0	.048	20.3
2	27.9	5.3	22.6	45.2	.034	20.3
4	27.0	5.3	21.7	43.4	.024	20.3
8	25.7	5.2	20.5	41.0	.017	20.3
15	24.5	5.2	19.3	38.6	.013	20.3
30	23.0	5.1	17.9	35.8	.0090	20.3
1 hr.	20.9	5.1	15.8	31.6	.0065	20.3
2	20.0	5.2	14.8	29.6	.0046	20.5
4	18.4	4.9	13.5	27.0	.0033	20.5
8	17.0	5.0	12.0	24.0	.0023	21.0
24	16.1	5.3	10.8	21.6	.0014	18.7

Retained on Sieve Mesh No.	Size (mm)	Sample wt. (grams)	Cumulative wt. (grams)	Cumulative wt. (per cent)
35	.500	3.92	3.92	7.84
60	.250	5.47	9.39	18.78
80	.177	3.70	13.09	26.18
120	.125	3.07	16.16	32.32
170	.080	3.10	19.26	38.52
230	.063	2.46	21.72	43.44
PAN		0.11	21.83	43.66

Other Data:
Sand Sample Wt. 21.87 g.

Percentage Sand	43.4
Percentage Silt	33.6
*Percentage Clay	23.0
Textural Designation	Loam

*less than 2 microns

Sample No. T.H. 67-8 Unit D
90' Below surface
Sample Wt. 50 g.

Time elapsed	Hydrometer reading (A)	Composite correction (B)	Corrected reading (C=A-B)	Percentage remaining in suspension	Diameter in mm	Temp. °C
15 sec.	36.0	3.8	32.2	64.4	.092	19.5
30	33.3	3.8	29.5	59.0	.066	19.5
1 min.	31.2	3.8	27.4	54.8	.047	19.5
2	29.0	3.8	25.2	50.4	.034	19.5
4	28.4	3.8	24.6	49.2	.024	19.5
8	26.3	3.8	22.5	45.0	.017	19.5
15	25.0	3.8	21.2	42.4	.013	19.5
30	23.5	3.8	19.7	39.4	.0091	19.6
1 hr.	21.7	4.0	17.7	35.4	.0064	20.0
2	20.0	4.3	15.7	31.4	.0046	20.1
4	18.0	4.1	13.9	27.8	.0033	20.6
8	16.3	4.2	12.1	24.2	.0023	21.0
24	15.2	4.2	11.0	22.0	.0014	19.5

Retained on Sieve Mesh No.	Size (mm)	Sample wt. (grams)	Cumulative wt. (grams)	Cumulative wt. (per cent)
35	.500	1.68	1.68	3.36
60	.250	4.27	5.95	11.90
80	.177	3.33	9.28	18.56
120	.125	3.90	13.18	26.36
170	.080	3.51	16.69	33.38
230	.063	3.26	19.95	39.90
PAN		0.38	20.33	40.66

Other Data:
Sand Sample Wt. 20.49 g.

Percentage Sand	39.9
Percentage Silt	36.3
*Percentage Clay	23.8
Textural Designation	Loam

*less than 2 microns

Sample No. T.H. 67-8 Unit E
25' Below surface
Sample Wt. 50 g.

Time elapsed	Hydrometer reading (A)	Composite correction (B)	Corrected reading (C=A-B)	Percentage remaining in suspension	Diameter in mm	Temp. °C
15 sec.	54	5.0	49.0	98.0	.079	20.0
30	53.0	5.0	48.0	96.0	.056	20.0
1 min.	52.2	5.0	47.2	94.4	.040	20.0
2	51.5	5.0	46.5	93.0	.028	20.0
4	51.7	5.0	46.7	93.4	.020	20.0
8	49.5	5.0	44.5	89.0	.014	20.0
15	46.0	5.0	41.0	82.0	.011	20.0
30	42.4	5.0	37.4	74.8	.0079	20.3
1 hr.	38.0	5.0	33.0	66.0	.0058	20.4
2	34.0	5.0	29.0	58.0	.0042	20.5
4	30.9	5.0	25.9	51.8	.0031	20.7
8	27.6	4.6	23.0	46.0	.0022	21.2
24	24.1	4.7	19.4	38.8	.0013	20.0

Retained on Sieve Mesh No.	Size (mm)	Sample wt. (grams)	Cumulative wt. (grams)	Cumulative wt. (per cent)
120	.125	0.21	0.21	0.42
170	.088	0.35	0.56	1.12
230	.063	0.48	1.04	2.08

Percentage Sand	2.1
Percentage Silt	54.1
*Percentage Clay	43.8
Textural Designation	Silty Clay

*less than 2 microns

Sample No. T.H. 67-8 Unit E
66' Below surface
Sample Wt. 50 g.

Time elapsed	Hydrometer reading (A)	Composite correction (B)	Corrected reading (C=A-B)	Percentage remaining in suspension	Diameter in mm	Temp. °C
15 sec.	53.0	3.4	49.6	99.2	.075	23.5
30	51.8	3.4	48.4	96.8	.054	23.5
1 min.	50.6	3.4	47.2	94.4	.038	23.5
2	49.3	3.4	45.9	91.8	.027	23.5
4	48.8	3.4	45.4	90.8	.020	23.5
8	47.0	3.4	43.6	87.2	.014	23.5
15	44.9	3.4	41.5	83.0	.010	23.6
30	42.4	3.3	39.1	78.2	.0075	23.7
1 hr.	40.3	3.6	36.7	73.4	.0054	23.7
2	38.1	3.7	34.4	68.8	.0039	23.4
4	36.0	3.8	32.2	64.4	.0028	23.0
8	34.0	4.0	30.0	60.0	.0020	23.0
24	31.1	4.7	26.4	52.8	.0012	20.5

Retained on Sieve Mesh No.	Size (mm)	Sample wt. (grams)	Cumulative wt. (grams)	Cumulative wt. (per cent)
60	.250	0.55	0.55	1.10
80	.177	0.33	0.88	1.76
120	.125	0.35	1.23	2.46
170	.088	0.57	1.80	3.60
230	.063	0.78	2.58	5.16
PAN		0.01	2.59	5.18

Other Data:
Sand Sample Wt. 2.56 g.

Percentage Sand	5.2
Percentage Silt	35.2
*Percentage Clay	59.6
Textural Designation	Clay

*less than 2 microns

Sample No. T.H. 67-8 Unit F
7' Below surface
Sample Wt. 50 g.

Time elapsed	Hydrometer reading (A)	Composite correction (B)	Corrected reading (C=A-B)	Percentage remaining in suspension	Diameter in mm	Temp. °C
15 sec.	34	5.1	28.9	57.8	.092	20.0
30	22.5	5.1	17.4	34.8	.070	20.0
1 min.	16.2	5.1	11.1	22.2	.052	20.0
2	15.0	5.1	9.9	19.8	.037	20.0
4	14.8	5.1	9.7	19.4	.026	20.0
8	14.0	5.0	9.0	18.0	.019	20.0
15	13.3	5.0	8.3	16.6	.014	20.2
30	12.9	5.0	7.9	15.8	.0096	20.3
1 hr.	12.2	5.0	7.2	14.4	.0068	20.5
2	11.2	4.8	6.4	12.8	.0048	20.6
4	10.2	4.3	5.9	11.8	.0034	21.0
8	10.1	4.2	5.9	11.8	.0024	21.0
24	10.5	4.9	5.6	11.2	.0014	20.0

Retained on Sieve Mesh No.	Size (mm)	Sample wt. (grams)	Cumulative wt. (grams)	Cumulative wt. (per cent)
60	.250	0.31	0.31	0.62
80	.177	1.01	1.32	2.64
120	.125	7.43	8.75	17.50
170	.088	14.97	23.72	47.44
230	.063	11.30	35.02	70.04
PAN		1.31	36.33	72.66

Other Data:
Sand Sample Wt. 36.38 g.

Percentage Sand 70.0
Percentage Silt 18.6
*Percentage Clay 11.4
Textural Designation Sandy Loam

*less than 2 microns

APPENDIX B. SIEVE ANALYSES OF SURFICIAL DEPOSITS

Sample	Retained on Sieve Mesh No.	Retained on Sieve Size (mm)	Sample weight (grams)	Cumulative weight (grams)	Cumulative weight (per cent)
RS Unit A	5	4.00	0.2	0.2	0.1
71' Below surface	10	2.00	0.1	0.3	-
(sample wt.	18	1.00	0.2	0.5	0.2
243.8 g.)	35	0.500	1.3	1.8	0.7
	45	0.354	4.6	6.4	2.6
	60	0.250	33.4	39.8	16.2
	80	0.177	67.7	107.5	43.7
	100	0.149	30.1	137.6	56.0
	120	0.125	25.8	163.4	66.5
	170	0.088	-	-	-
	230	0.063	68.6	232.0	94.5
	PAN		13.5	245.5	100.0
RS Unit A	5	4.00	-	-	-
81' Below surface	10	2.00	-	-	-
(sample wt.	18	1.00	0.2	0.2	0.1
244.0 g.)	35	0.500	1.3	1.5	0.6
	45	0.354	9.1	10.6	4.3
	60	0.250	52.7	63.3	25.8
	80	0.177	111.0	174.3	71.3
	100	0.149	-	-	-
	120	0.125	56.2	230.5	94.3
	170	0.088	-	-	-
	230	0.063	12.2	242.7	99.3
	PAN		1.7	244.4	100.0
RS Unit A	5	4.00	0.6	0.6	0.2
98' Below surface	10	2.00	0.8	1.4	0.5
(sample wt.	18	1.00	1.5	2.9	1.1
253.5 g.)	35	0.500	7.9	10.8	4.2
	45	0.354	-	-	-
	60	0.250	66.2	77.0	30.4
	80	0.177	59.8	136.8	54.0
	100	0.149	-	-	-
	120	0.125	65.0	201.8	79.6
	170	0.088	-	-	-
	230	0.063	46.0	247.8	97.7
	PAN		6.1	253.9	100.0

Sample	Retained on Sieve Mesh No.	Size (mm)	Sample weight (grams)	Cumulative weight (grams)	Cumulative weight (per cent)
RS Unit C*	5	4.00	-	-	-
40' Below surface	10	2.00	-	-	-
(sample wt.	18	1.00	35.5	36.6	6.1
601.7 g.)	35	0.500	73.1	109.7	18.2
	45	0.354	151.7	261.4	43.4
	60	0.250	189.0	450.4	74.8
	80	0.177	93.8	544.2	90.4
	100	0.149	27.0	571.2	94.9
	120	0.125	13.3	584.5	97.1
	170	0.088	6.7	591.2	98.2
	230	0.063	7.0	598.2	99.4
	PAN		3.4	601.6	100.0
RS Unit C**		12.70	182.7	182.7	12.3
58' Below surface		6.35	189.6	372.3	25.1
(sample wt.	5	4.00	161.7	534.0	36.1
	10	2.00	470.4	1004.4	67.6
T.H. 67-1 Unit C	18	1.00	3.16	3.16	4.29
43'-49' Below surface	35	0.500	4.78	7.94	10.78
(sample wt.	60	0.250	20.50	28.44	38.60
73.71 g.)	120	0.125	32.51	60.95	82.73
	170	0.088	6.70	67.65	91.83
	230	0.063	3.98	71.63	97.23
	PAN		2.04	73.67	100.00
T.H. 67-1 Unit C	18	1.00	2.60	2.60	2.05
49'-60' Below surface	35	0.500	4.00	6.60	5.21
(sample wt.	60	0.250	22.83	29.43	23.24
126.85 g.)	80	0.177	35.81	65.24	51.52
	100	0.149	18.32	83.56	65.98
	120	0.125	14.92	98.48	77.76
	170	0.088	18.11	116.59	92.06
	230	0.063	7.68	124.27	98.13
	PAN		2.37	126.64	100.00

Bulk Sample	Weight (grams)	Weight (per cent)
* +2 mm coal	10.7	0.9
+2 mm gravel	116.3	7.8
-2 mm sand	1228.9	91.3
**-2 mm	477.4	32.4

Sample	Retained on Sieve Mesh No.	Size (mm)	Sample weight (grams)	Cumulative weight (grams)	Cumulative weight (per cent)
T.H. 67-2 Unit C	18	1.00	4.78	4.78	4.84
90'-102' Below	35	0.500	4.78	9.56	9.68
surface	60	0.250	35.07	44.63	45.17
(sample wt.	120	0.125	44.03	83.66	84.68
98.97 g.)	170	0.088	7.23	95.89	97.05
	230	0.063	1.79	97.68	98.84
	PAN		1.02	98.80	100.00
T.H. 67-2 Unit C	18	1.00	1.52	1.52	1.41
110'-113' Below	35	0.500	2.83	4.35	4.03
surface	60	0.250	39.69	44.04	40.83
(sample wt.	120	0.125	52.06	96.10	89.09
108.01 g.)	170	0.088	8.69	104.79	97.14
	230	0.063	2.10	106.89	99.09
	PAN		0.98	107.87	100.00
T.H. 67-3 Unit C	18	1.00	4.42	4.42	4.36
74'-79' Below	35	0.500	7.30	11.72	11.57
surface	60	0.250	37.61	49.33	48.71
(sample wt.	120	0.125	41.21	90.54	89.40
101.60 g.)	170	0.088	5.89	96.43	95.21
	230	0.063	2.79	99.22	97.97
	PAN		2.06	101.28	100.00
T.H. 67-4 Unit C	18	1.00	6.19	6.19	6.11
73'-75' Below surface	35	0.500	10.00	16.19	15.98
(sample wt.	60	0.250	28.70	44.89	44.31
101.73 g.)	120	0.125	42.83	87.72	86.59
	170	0.088	7.50	95.22	96.95
	230	0.063	3.00	98.22	96.95
	PAN		3.09	101.31	100.00
T.H. 67-5 Unit F	18	1.00	0.05	0.05	0.04
5'-10' Below surface	35	0.500	0.60	0.65	0.50
(sample wt.	60	0.250	29.70	30.35	23.54
129.11 g.)	80	0.177	55.93	86.28	66.91
	100	0.149	17.51	103.79	80.49
	120	0.125	7.63	111.42	86.41
	230	0.063	16.41	127.83	99.14
	PAN		1.11	128.94	100.00

Sample	Retained on Sieve Mesh No.	Retained on Sieve Size (mm)	Sample weight (grams)	Cumulative weight (grams)	Cumulative weight (per cent)
T.H. 67-5 Unit F	35	0.500	0.09	0.09	0.14
25'-30' Below surface	60	0.250	7.38	7.47	11.82
(sample wt.	80	0.177	18.50	25.97	41.08
63.28 g.)	100	0.149	11.00	36.97	58.48
	120	0.125	10.55	47.52	75.17
	170	0.088	12.40	59.92	94.78
	230	0.063	3.20	63.12	99.84
	PAN		0.10	63.22	100.00
T.H. 67-5 Unit C	18	1.00	5.50	5.50	6.94
81-84' Below surface	35	0.500	4.67	10.17	12.84
(sample wt.	60	0.250	22.25	32.42	40.92
79.38 g.)	120	0.125	34.80	67.22	84.84
	170	0.088	6.05	73.27	92.48
	230	0.063	3.15	76.42	96.45
	PAN		2.81	79.23	100.00
T.H. 67-5 Unit C	18	1.00	3.53	3.53	4.03
90'-96' Below surface	35	0.500	5.81	9.34	10.66
(sample wt.	60	0.250	22.52	31.86	36.37
87.78 g.)	120	0.125	41.65	73.51	83.91
	170	0.088	10.00	83.51	95.32
	230	0.063	2.68	86.19	98.38
	PAN		1.42	87.61	100.00
T.H. 67-5 Unit C	10	2.00	1.27	1.27	1.58
96'-102' Below	18	1.00	2.35	3.62	4.50
surface	35	0.500	6.13	9.75	12.11
(sample wt.	60	0.250	18.72	28.47	35.35
80.60 g.)	120	0.125	27.40	55.87	69.38
	170	0.088	12.93	68.70	85.43
	230	0.063	7.92	76.72	95.27
	PAN		3.81	80.53	100.00
T.H. 67-6 Unit A	18	1.00	0.57	0.57	0.86
112'-117' Below	35	0.500	0.72	1.29	1.96
surface	60	0.250	24.55	25.84	39.20
(sample wt.	120	0.125	34.56	60.40	91.64
66.01 g.)	230	0.063	4.90	65.30	99.07
	PAN		0.61	65.91	100.00

Sample	Retained on Sieve Mesh No.	Size (mm)	Sample weight (grams)	Cumulative weight (grams)	Cumulative weight (per cent)
T.H. 67-6 Unit A	18	1.00	0.41	0.41	0.74
140'-142' Below	35	0.500	1.12	1.53	2.76
surface	60	0.250	26.25	27.78	50.05
(sample wt.	120	0.125	25.02	52.80	95.12
55.60 g.)	170	0.088	2.20	55.00	99.08
	230	0.063	0.42	55.42	99.84
	PAN		0.09	55.51	100.00
T.H. 67-6* Unit A	10	2.00	1.27	1.27	1.73
160'-168' Below	18	1.00	0.30	1.57	2.13
surface	35	0.500	0.85	2.42	3.29
(sample wt.	60	0.250	38.51	40.93	55.62
74.62 g.)	120	0.125	31.33	72.26	98.19
	170	0.088	0.99	73.25	99.54
	230	0.063	0.22	73.47	99.84
	PAN		0.12	73.59	100.00
T.H. 67-6 Unit A	5	4.00	3.97	3.97	3.63
170'-178' Below	10	2.00	5.58	9.55	8.73
surface	18	1.00	4.71	14.26	13.03
(sample wt.	35	0.500	9.21	23.47	21.45
109.52 g.)	60	0.250	57.47	80.94	73.97
	120	0.125	26.38	107.32	98.07
	170	0.088	1.60	108.92	99.53
	230	0.063	0.41	109.33	99.91
	PAN		0.10	109.43	100.00
T.H. 67-6** Unit C	18	1.00	13.40	13.40	11.26
57'-63' Below surface	35	0.500	20.08	33.48	28.12
(sample wt.	60	0.250	46.70	80.18	67.35
119.42 g.)	120	0.125	31.22	111.40	93.57
	170	0.088	4.60	116.00	97.44
	230	0.063	1.57	117.57	98.76
	PAN		1.48	119.05	100.00

*Percentage loss by weight: 1.38

**Bulk sample >2 mm , 24.83%

Sample	Retained on Sieve Mesh No.	Size (mm)	Sample weight (grams)	Cumulative weight (grams)	Cumulative weight (per cent)
T.H. 67-6 Unit C	18	1.00	1.80	1.80	1.62
82'-86' Below surface	35	0.500	2.67	4.47	4.03
(sample wt.	60	0.250	20.80	25.27	22.77
111.20 g.)	80	0.177	40.00	65.27	58.81
	100	0.149	15.30	80.57	72.60
	120	0.125	6.17	86.74	78.16
	170	0.088	17.65	104.39	94.06
	230	0.063	5.00	109.39	98.57
	PAN		1.59	110.98	100.00
T.H. 67-6 Unit C	18	1.00	0.45	0.45	0.78
90'-94' Below surface	35	0.500	0.95	1.40	2.42
(sample wt.	60	0.250	5.72	7.12	12.32
57.83 g.)	80	0.177	13.98	21.10	36.52
	120	0.125	20.35	41.45	71.75
	170	0.088	11.20	52.65	91.14
	230	0.063	4.09	56.74	98.22
	PAN		1.03	57.77	100.00
T.H. 67-7 Unit C	18	1.00	24.08	24.08	16.58
107'-110' Below	35	0.500	31.80	55.88	38.48
surface	60	0.250	46.37	102.25	70.42
(sample wt.	120	0.125	31.09	133.34	91.83
145.40 g.)	170	0.088	7.55	140.89	97.03
	230	0.063	2.80	143.69	98.96
	PAN		1.51	145.20	100.00
T.H. 67-7 Unit C	18	1.00	6.39	6.39	4.43
116'-119' Below	35	0.500	11.21	17.60	12.21
surface	60	0.250	42.62	60.22	41.78
(sample wt.	120	0.125	64.99	125.21	86.88
144.29 g.)	170	0.088	13.61	138.82	96.32
	230	0.063	4.41	143.23	99.38
	PAN		0.89	144.12	100.00
T.H. 67-7 Unit E	60	0.250	1.90	1.90	2.22
40'-46' Below surface	80	0.177	7.65	9.55	11.17
(sample wt.	120	0.125	17.70	27.25	31.86
86.29 g.)	170	0.088	26.64	53.89	63.01
	200	0.074	12.72	66.60	77.87
	230	0.063	8.57	75.17	87.89
	PAN		10.36	85.53	100.00

Sample	Retained on Sieve Mesh No.	Size (mm)	Sample weight (grams)	Cumulative weight (grams)	Cumulative weight (per cent)
T.H. 67-8 Unit C	18	1.00	3.43	3.43	2.75
99'-104' Below	35	0.500	4.88	8.31	6.65
surface	60	0.250	31.88	40.19	32.17
(sample wt.	80	0.177	53.32	93.51	74.85
125.10 g.)	100	0.149	15.60	109.11	87.34
	120	0.125	5.01	114.12	91.35
	170	0.088	9.69	123.81	99.10
	230	0.063	0.93	124.74	99.85
	PAN		0.19	124.93	100.00
T.H. 67-8 Unit C	18	1.000	2.30	2.30	2.81
115'-118' Below	35	0.500	4.50	6.80	8.32
surface	60	0.250	15.30	22.10	27.04
(sample wt.	80	0.177	25.03	47.13	57.66
82.29 g.)	120	0.125	18.72	65.85	80.56
	170	0.088	10.49	76.34	93.39
	230	0.063	3.51	79.85	97.69
	PAN		1.89	81.74	100.00
T.H. 67-8 Unit C	10	2.00	1.90	1.90	1.42
132'-135' Below	18	1.000	6.05	7.95	5.93
surface	35	0.500	14.28	22.23	16.58
(sample wt.	60	0.250	41.33	63.56	47.41
134.65 g.)	80	0.177	29.72	93.28	69.58
	120	0.125	25.20	118.48	88.37
	170	0.088	8.79	127.27	94.93
	230	0.063	3.80	131.07	97.76
	PAN		3.00	134.07	100.00
T.H. 65-1 Unit C	10	2.0	18.04	-	6.6
90'-95' Below surface	18	1.0	18.38	-	13.3
(sample wt.	35	0.50	21.36	-	27.1
272.4 g.	45	0.35	35.60	-	40.1
	60	0.25	64.06	-	63.5
	80	0.177	29.16	-	82.1
	120	0.125	7.85	-	90.6
	170	0.088	13.77	-	95.6
	PAN		12.18	-	100.1

Sample	Retained on Sieve		Sample weight (grams)	Cumulative weight (grams)	Cumulative weight (per cent)
	Mesh No.	Size (mm)			
T.H. 65-1 Unit A	18	1.0	0.33	-	0.6
103'-112' Below	35	0.50	0.65	-	1.2
surface	45	0.35	5.75	-	4.6
(sample wt.	60	0.25	21.58	-	17.4
167.7 g.)	80	0.177	25.88	-	42.0
	120	0.125	13.76	-	63.0
	170	0.088	31.01	-	81.5
	PAN		31.14	-	100.0
T.H. 65-2 Unit A	10	2.0	1.84	-	0.6
120'-128' Below	18	1.0	1.91	-	1.2
surface	35	0.50	9.96	-	5.3
(sample wt.	45	0.35	43.43	-	18.5
330.3 g.)	60	0.25	85.00	-	44.2
	80	0.177	55.73	-	71.9
	120	0.125	16.32	-	86.8
	170	0.088	28.17	-	95.3
	PAN		15.52	-	100.0
T.H. 65-3 Unit A	10	2.0	3.44	-	1.4
125'-130' Below	18	1.0	3.01	-	2.6
surface	35	0.50	6.64	-	6.2
(sample wt.	45	0.35	27.62	-	17.6
242.0 g.)	60	0.25	74.67	-	48.5
	80	0.177	41.16	-	78.8
	120	0.125	10.62	-	91.3
	170	0.088	15.55	-	97.7
	PAN		5.34	-	99.9
T.H. 65-3 Unit A	10	2.0	0.35	-	0.1
140'-145' Below	18	1.0	0.20	-	0.2
surface	35	0.50	0.94	-	0.7
(sample wt.	45	0.35	7.74	-	2.9
351.8 g.)	60	0.25	61.72	-	20.5
	80	0.177	68.77	-	52.8
	120	0.125	25.10	-	71.6
	170	0.088	50.50	-	86.0
	PAN		50.42	-	100.0

Sample	Retained on Sieve Mesh No.	Size (mm)	Sample weight (grams)	Cumulative weight (grams)	Cumulative weight (per cent)
T.H. 65-3 Unit A	10	2.0	0.77	-	0.3
115'-160' Below	18	1.0	0.48	-	0.5
surface	35	0.50	1.55	-	1.2
(sample wt.	45	0.35	13.41	-	6.4
257.2 g.)	60	0.25	59.91	-	29.7
	80	0.177	63.36	-	68.7
	120	0.125	14.93	-	85.6
	170	0.088	27.45	-	96.3
	PAN		9.18	-	99.9
T.H. 65-3 Unit A	10	2.0	31.38	-	9.2
180'-184' Below	18	1.0	15.39	-	13.7
surface	35	0.50	23.20	-	22.1
(sample wt.	45	0.35	51.89	-	37.3
342.0 g.)	60	0.25	105.21	-	68.0
	80	0.177	37.15	-	86.4
	120	0.125	9.04	-	93.6
	170	0.088	14.08	-	97.7
	PAN		8.18	-	100.1
T.H. 65-3 Unit A	10	2.0	76.00	-	18.7
184'-187.5' Below	18	1.0	21.79	-	24.1
surface	35	0.50	55.71	-	40.3
(sample wt.	45	0.35	58.75	-	54.8
405.2 g.)	60	0.25	107.48	-	81.4
	80	0.177	24.05	-	93.6
	120	0.125	5.16	-	98.0
	170	0.088	5.90	-	99.4
	PAN		2.45	-	100.0
T.H. 65-3 Unit C	10	2.0	0.14	-	0.1
91-93' Below surface	18	1.0	0.47	-	0.3
(sample wt.	35	0.50	9.80	-	6.1
209.9 g.)	45	0.35	29.50	-	20.2
	60	0.25	60.64	-	49.1
	80	0.177	26.74	-	72.3
	120	0.125	11.15	-	86.4
	170	0.088	18.76	-	95.3
	PAN		9.94	-	100.0

Sample	Retained on Sieve Mesh No.	Size (mm)	Sample weight (grams)	Cumulative weight (grams)	Cumulative weight (per cent)
T.H. M1 Unit A	18	1.00	0.48	0.48	0.62
114'-134' Below	35	0.500	3.08	3.56	4.59
surface	60	0.250	28.60	32.16	41.49
(sample wt.	120	0.125	39.20	71.36	92.07
77.58 g.)	170	0.088	4.95	76.31	98.45
	230	0.063	1.08	77.39	99.85
	PAN		0.12	77.51	100.00
T.H. M1 Unit A	18	1.00	0.02	0.02	0.03
154'-164' Below	35	0.500	1.32	1.34	1.69
surface	60	0.250	33.97	35.31	44.47
(sample wt.	80	0.177	25.98	61.29	77.18
79.80 g.)	120	0.125	11.81	73.10	92.05
	170	0.088	4.49	77.59	97.71
	230	0.063	1.15	78.74	99.16
	PAN		0.67	79.41	100.00
T.H. M1 Unit C	18	1.00	3.35	3.35	3.9
97'-114' Below	35	0.500	6.23	9.58	11.1
surface	60	0.250	40.57	50.15	57.9
(sample wt.	120	0.125	31.30	81.45	94.2
87.25 g.)	170	0.088	4.38	85.83	99.0
	230	0.063	0.72	86.55	99.9
	PAN		0.12	86.67	100.0
T.H. EP1 Unit C	18	1.0	9.29	9.29	3.90
76'-79' Below surface	35	0.50	19.11	39.37	16.53
(sample wt.	45	0.35	41.91	81.28	34.12
238.72)	60	0.25	55.58	136.86	57.45
	80	0.177	26.96	192.82	80.94
	120	0.125	10.70	220.21	92.44
	170	0.088	10.61	230.82	96.89
	PAN		7.40	238.22	100.00

APPENDIX C. LITHOLOGIC DESCRIPTION OF TEST HOLES

TEST HOLE 65-1 DESCRIPTIVE LOG

Location: 122 feet south, 46 feet east, SW Corner, Sec. 36, Tp. 51, R. 26, W. 4

Surface Elevation: 2,285 feet

Thickness (feet)	Cumulative depth (feet)	Description
5	5	Clay, yellowish grey, bedded
5	10	Clay, silty, yellowish grey and medium light grey, mottled
5	15	Clay, yellowish grey
5	20	Clay, silty, light olive grey and medium grey
15	35	Clay, light olive grey
10	45	Clay, light olive grey and olive grey, well bedded
5	50	Clay, light olive grey
5	55	Till, sandy, light olive grey with pebbles and coal fragments
5	60	Gravel, fine with light olive grey sandy clay and abundant coal fragments
9	69	Sand, quartz, yellowish grey, subangular to round with pebbles and granular coal
6	75	Clay, sandy, light olive grey, pebbles and coal fragments
5	80	Clay, sandy, olive grey with fine gravel and abundant coal fragments
10	90	Sand, quartz, yellowish grey with sandy clay, pebbles and coal fragments
5	95	Sand, quartz, yellowish grey, subangular to round
8	103	Till, sandy, light olive grey, pebbles and coal fragments
9	112	Sand, quartz, light olive grey with yellowish and greenish colored grains, black chert and granular coal, subangular to round
3	115	Shale, silty, light grey, mica, calcareous
5	120	Shale, silty, olive grey, calcareous
2.5	122.5	Shale, light olive grey, concretions

TEST HOLE 65-2 DESCRIPTIVE LOG

Location: 2,972 feet south, 36 feet east, NW Corner, Sec. 36, Tp. 51, R. 26, W. 4th Mer.
Surface Elevation: 2,277 feet

Thickness (feet)	Cumulative depth (feet)	Description
10	10	Clay, yellowish grey, carbonaceous material
5	15	Clay, yellowish grey and light olive grey, mottled clay ironstone concretions
10	25	Clay, light olive grey
5	30	Clay, light olive grey, well bedded, coal fragments and clay ironstone concretions
5	35	Clay, light olive grey, coal fragments and pebbles
10	45	Clay, light olive grey, coal fragments
5	50	Clay, yellowish grey and light olive grey, mottled
5	55	Clay, light olive grey, carbonaceous material
5	60	Clay, light olive grey
5	65	Till, sandy, medium grey, quartz and granite pebbles, coal fragments
25	90	Gravel and sand, fine with medium grey sandy clay, abundant coal fragments
10	100	Till, very sandy, medium grey, pebbles and coal fragments
5	105	Till, very sandy, medium light grey, fine gravel and sand, abundant coal fragments
7	112	Till, sandy, pebbles and coal fragments
16	128	Sand, quartz, light olive grey with yellowish and greenish colored grains, black chert and granular coal, subangular to round
4	132	Sandstone, silty, fine, light grey
3	135	Shale, silty, light olive grey
5	140	Sandstone, silty, fine, light grey

TEST HOLE 65-3 DESCRIPTIVE LOG

Location: 575 feet south, 80 feet east, NW Corner, Sec. 36, Tp. 51, R. 26, W. 4th Mer.
Surface Elevation: 2,272 feet

Thickness (feet)	Cumulative depth (feet)	Description
5	5	Clay, yellowish grey
5	10	Clay, yellowish grey and olive grey, mottled, minor coal fragments, concretions
5	15	Clay, yellowish grey and medium grey, mottled
5	20	Clay, silty, medium grey and yellowish grey
5	25	Clay, medium grey, well bedded
15	40	Clay, light olive grey, coal fragments, clay ironstone concretions
10	50	Clay, light olive grey
5	55	Clay, light olive grey, concretions
5	60	Till, light olive grey, coal fragments, pebbles
20	80	Till, sandy, light olive grey, abundant coal fragments, pebbles
5	85	Sand, quartz, pale yellowish brown with black grains
5	90	Sand, quartz, pale yellowish brown, sandy light olive clay
3	93	Sand quartz, pale yellowish brown
2	95	Till, silty, light olive grey
4	99	Till, light olive grey, clay ironstone concretions, quartz grains
6	105	Till, olive grey
8	113	Till, sandy, olive grey with granite pebbles
67	180	Sand, quartz, yellowish and greenish colored grains, black chert, granular coal, few carbonate grains, large limonite grains, subangular to round
7.5	187.5	Sand, large quartz grains, large pieces of clay ironstone concretions
2.5	190	Shale, sandy, greenish grey, clay ironstone concretions
5	195	Shale, light grey, clay ironstone concretions

TEST HOLE 65-4 DRILLER'S LOG

Location: 1,106 feet north, 60 feet east, NW Corner, Sec. 36, Tp. 51, R. 26, W. 4th Mer.
Surface Elevation: 2,275 feet

Thickness (feet)	Cumulative depth (feet)	Description
17	17	Clay, brown
43	60	Clay, grey, no pebbles, no coal fragments
44	104	Clay, grey, pebbles and coal fragments
	104	Sand, few inches
8	112	Clay, grey, pebbles and coal fragments
6	118	Sand, fine, grey
4	122	Clay, fine
63	185	Sand, fine, grey
5	190	Sand, fine, grey, with clay ironstone concretions
10	200	Shale, light grey

TEST HOLE 67-1 DESCRIPTIVE LOG (FIELD)

Location: Lsd. 12, Sec. 11, Tp. 51, R. 26, W. 4th Mer.

Surface Elevation: 2,287 feet

Thickness (feet)	Cumulative depth (feet)	Description
5	5	Sand, silty, dark yellowish brown (10YR 4/2)
7	12	Sand, light olive grey (5Y 5/2) and medium light grey (N6), mottled, iron stained
7	19	Sand, silty, light olive grey (5Y 5/1), slightly mottled, poorly bedded, water bearing
4	23	Clay, olive grey (5Y 4/1), massive and finely bedded layers
9	32	Clay, silty, olive grey (5Y 4/1)
4	36	Clay, olive grey (5Y 4/1), well bedded
7	43	Till, olive grey (5Y 3/1), pebbles and coal fragments
16	59	Sand, with granites
4	63	Till, olive grey (5Y 3/2), pebbles, coal fragments, concretions
2.5	65.5	Shale, silty, medium light grey (N6)
2	67.5	Shale, dark greenish grey (5GY 4/1)
1.5	69	Shale, olive black (5Y 2/1)
1	70	Coal
3	73	Shale, light olive grey (5Y 5/2)
2	75	Shale, sandy, medium grey (N5)
6	81	Sandstone, fine grained, silty, medium grey (N5)

TEST HOLE 67-2 DESCRIPTIVE LOG (FIELD)

Location: Lsd. 12, Sec. 11, Tp. 51, R. 26, W. 4th Mer.

Surface Elevation: 2,299 feet

Thickness (feet)	Cumulative depth (feet)	Description
12	12	Sand fine to medium, silty, light olive grey (5Y 5/2), wet at 5 feet
1.5	13.5	Clay, medium light grey (N6) with thin layers of white calcareous material
6.5	20	Sand, very fine, silty, light olive grey (5Y 5/2), mottled and bedded
17	37	Sand, fine, silty, with thin clay layers
4	41	Silt, olive grey (5Y 4/1) with sand layers
14	55	Clay, silty, olive grey (5Y 4/1)
5	60	Clay, olive grey (5Y 3/1)
4	64	Clay, olive grey (5Y 3/1)
4	68	Silt
5	73	Clay, silty massive
4	77	Till (5Y 3/1), with coal fragments and small pebbles
12	89	Sand, with silty sand layers, granite pebbles
17	106	Sand
4	110	Sand, more silt in sand
5	115	Sand
5	120	Till, with bedrock chips and clay ironstone concretions
4	124	Shale, sandy, bentonitic
4	128	Shale, dark greenish grey (5GY 4/1) and black carbonaceous (N1)
4	132	Shale, greyish olive green (5GY 3/2) and dark greenish grey (5GY 4/1), thin coal layer
2	134	Shale, bentonitic, dark greenish grey (5GY/4/1)

TEST HOLE 67-3 DESCRIPTIVE LOG (FIELD)

Location: Lsd. 9, Sec. 18, Tp. 51, R. 25, W. 4th Mer.

Surface Elevation: 2,271 feet

Thickness (feet)	Cumulative depth (feet)	Description
11	11	Sand, silty, light olive grey (5Y 5/4), heavy calcification
1	12	Clay, silty, wet, light olive grey (5Y 5/4), heavy calcification along decayed roots
10	22	Sand, silty, bedded
2	24	Silt
4	28	Clay, olive grey (5GY 4/1), well bedded
4	32	Silt, minor bedding
4	36	Clay, well bedded
9	45	Clay, silty, (5GY 4/1), massive
4	49	Silt, minor bedding
2	51	Clay, 5GY 4/1, well bedded
9	60	Till, olive grey (5Y 4/1)
2	62	Till, olive grey (5Y 3/1) to olive black, coal fragments
2	64	Till, sandy with bedrock chips and coal fragments, olive grey (5Y 3/1) to olive black
8	72	Till, olive grey (5Y 3/1) to black, fewer pebbles and less coal
7	79	Sand with pebbles
3	82	Till, sandy, high in bedrock material
4	86	Sand, some bedrock material
2	88	Shale, greenish grey (5GY 5/1)
1	89	Sandstone, greenish grey (5G 5/1)
4	93	Shale, greenish grey (5G 5. 5/1)
7	100	Shale, light olive grey (5Y 5/1)

TEST HOLE 67-4 DESCRIPTIVE LOG (FIELD)

Location: Lsd. 13, Sec. 12, Tp. 51, R. 26, W. 4th Mer.

Surface Elevation: 2,280 feet

Thickness (feet)	Cumulative depth (feet)	Description
5	5	Sand, silty, light olive grey (5Y 5/2) mottled, poorly bedded
1	6	Sand, greyish olive and yellowish, mottled, moist
2	8	Sand, silty, olive grey (5Y 4/1), moderately bedded
6.5	14.5	Sand, silty, olive grey (5Y 4/1), poorly bedded 8-12, well bedded 12-14.5
0.5	15	Clay, well bedded
7	22	Silt
6	28	Sand, silty
6	34	Silt, massive
17	51	Clay
2	53	Clay, silty, olive grey (5Y 3.5/1), massive alternating with bedded material
5	58	Clay, silty
6	60	Clay
7	67	Clay, silty, olive grey (5Y 4/1), massive and bedded
2	69	Till, sandy
4	73	Till, olive grey (5Y 3/1)
6	79	Sand, silty with coal fragments
20	99	Till, dark grey (N3) with high bedrock content
3	102	Shale, olive grey (5Y 4/1) carbonaceous

TEST HOLE 67-5 DESCRIPTIVE LOG (FIELD)

Location: Lsd. 15, Sec. 9, Tp. 51, R. 26, W. 4th Mer.

Surface Elevation: 2,309 feet

Thickness (feet)	Cumulative depth (feet)	Description
30	30	Sand, fine to medium, yellowish brown
4	34	Sand, silty
16	50	Clay, silty
8	58	Clay, olive grey (5Y 3.5/1), well bedded
10	68	Clay, silty, olive grey (5Y 3.5/1)
16	84	Sand, silty
3	87	Sand, coal fragments abundant, bedrock chips
1	88	Clay, sandy, olive grey (5Y 3.5/1), coal fragments
7	95	Sand, medium to coarse, thin clay layer 90'
4	99	Sand, fine gravel lense, with silt layers
12	111	Sand, silty with clay layers, coal fragments and bed-rock fragments
9	120	Till, with coal fragments, shale pebbles, and concretions
5	125	Shale

TEST HOLE 67-6 DESCRIPTIVE LOG (FIELD)

Location: Lsd. 8, Sec. 13, Tp. 51, R. 27, W. 4th Mer.

Surface Elevation: 2,300 feet

Thickness (feet)	Cumulative depth (feet)	Description
5	5	Sand, silty, dusky yellow (5Y 5/4), minor bedding
11	16	Sand, silty, light olive grey (5Y 5/2.5), massive, lower portion wet
1	17	Clay, light olive grey (5Y 5/4), mottled with streaks of medium grey (N5) clay
1	18	Sand
6	24	Clay, light olive grey (5Y 4/1), massive
4	28	Clay, light olive grey (5Y 3.5/1), well bedded with very fine sand to silt layers
8	36	Sand
6	42	Clay, silty, olive grey (5Y 4/1)
9	51	Clay, silty, olive grey (5Y 4/1)
6	57	Till?, sandy, olive grey (5Y 4/1), bedded material with coal fragments and granite pebbles
2	59	Sand, coarse
20	79	Sand, some fine gravel, silt and clay layers
3	82	Silt
4	86	Sand, fine to medium
4	90	Silt, olive grey (5Y 4/1)
4	94	Sand, fine to medium
4	98	Clay, olive grey (5Y 3.5/1) with sand layers
10	108	Till, high in bedrock fragments
34	142	Sand, fine to medium
38	180	Sand, fine to medium, concretions, bedrock pebbles, "petrified wood" pebbles
2	182	Shale

TEST HOLE 67-7 DESCRIPTIVE LOG (FIELD)

Location: Lsd. 4, Sec. 24, Tp. 51, R. 26, W. 4th Mer.

Surface Elevation: 2,313 feet

Thickness (feet)	Cumulative depth (feet)	Description
5	5	Sand, silty, dark yellowish brown (10YR 4/2)
10	15	Sand, silty, light olive grey (5Y 4/2), massive, calcified
15	30	Sand, silty, dusky yellow (5Y 5/4)
22	52	Sand, light olive grey (5Y 4/2), with clay layers
18	70	Clay, very sandy
8	78	Clay, silty
4	82	Clay, olive grey (5Y 3.5/1), interbedded massive beds to thin well bedded clays
12	94	Clay, olive grey (5Y 4/1)
4	98	Clay, olive grey (5Y 3.5/1), massive beds alternating with finely bedded material
5	103	Till, olive grey (5Y 3/1) with pebbles and coal fragments
4	107	Gravel, fine and coarse sand with clay layers
4	111	Gravel, fine and coarse sand, abundant granites
2	113	Clay, pebbles, bedded
3	116	Sand, coarse and fine gravel with clay layers
4	120	Sand, medium to coarse, thin gravel at 120' containing abundant bedrock material and concretions
3	123	Shale
11	134	Sandstone, silty, light grey (N7)
2	136	Shale, dusky yellowish brown (10YR 2/2), carbonaceous

TEST HOLE 67-8 DESCRIPTIVE LOG (FIELD)

Location: Lsd. 8, Sec. 26, Tp. 51, R. 26, W. 4th Mer.

Surface Elevation: 2,302 feet

Thickness (feet)	Cumulative depth (feet)	Description
25	25	Sand, dusky yellow (5Y 5/4)
8	33	Clay, sandy, light olive grey (5Y 4/1)
22	55	Clay, silty (5Y 4/1)
20	75	Clay, olive grey (5Y 4/1)
2	77	Clay, olive grey (5Y 4/1), massive silt layers alternating with bedded clay
18	95	Till, olive grey (5Y 3.5/1), sandy at 88'
4	99	Sand and clay layers
2	101	Sand, coarse with large pebbles
2	103	Sand, medium to coarse
13	116	Sand with silt and clay layers
2	118	Sand
4	122	Sand with clay layers
1	123	Sand
12	135	Sand and clay layers
6	141	Till
7	148	Sand with clay layers
1	149	Shale

TEST HOLE EP1 DESCRIPTIVE LOG*

Location: Lsd. 14, Sec. 15, Tp. 51, R. 26, W. 4th Mer.

Surface Elevation: 2,313 feet

Thickness (feet)	Cumulative depth (feet)	Description
30	30	Sand
10	40	Sand, silty
13	63	Clay, silty
11	74	Till
11	85	Sand, silty
7	92	Till
77	169	Sand, bedrock pebbles 157-169
8	177	Shale, olive black
2	179	Coal
11	190	Shale, light olive grey

*E-log interpretation shown in figure 6.

TEST HOLE EP2 DESCRIPTIVE LOG

Location: Lsd. 14, Sec. 15, Tp. 51, R. 26, W. 4th Mer.

Surface Elevation: Approximately 2,305 feet

Thickness (feet)	Cumulative depth (feet)	Description
15	15	Sand, yellowish grey
15	30	No samples
15	45	Sand, light olive grey
15	60	No samples
12	72	Till, light olive grey, coal fragments and pebbles
2	74	No samples
1	75	Sand
40	115	No samples
5	120	Sand
10	130	No samples
4	134	Sand, sandstone pebbles and concretions
16	150	Sand
15	165	Sand
4	169	Sand
6	175	Sand, abundant concretion pebbles and bedrock cuttings
	175	Top of bedrock

TEST HOLE EP4 DRILLER'S LOG*

Location: Lsd. 3, Sec. 27, Tp. 51, R. 26, W. 4th Mer.

Surface Elevation: 2,301 feet

Thickness (feet)	Cumulative depth (feet)	Description
32	32	Oxidized sandy clay
10	42	Soft oxidized silt
43.5	85.5	Harder, grey silty clay
16.5	102	Grey till, small boulders and pebbles
31	133	Grey till
6	139	Grey sand
8	147	Sand with clay layers
67	214	Sand, few thin clay layers
1	215	Coarse sand, fine gravel and coal
17	232	
9	243	Shale

*Electric log of test hole and writer's interpretation shown in figure 6.

TEST HOLE M1 DRILLER'S LOG

Location: Lsd. 7, Sec. 17, Tp. 51, R. 26, W. 4th Mer.

Surface Elevation: 2,323 feet

Thickness (feet)	Cumulative depth (feet)	Description
31	31	Sand, medium to coarse
23	54	Clay, sandy
43	97	Till, sandy with pebbles
17	114	Sand, fine to medium
2	116	Clay layer
48	164	Sand
6	170	Sand with bedrock fragments and concretions
4	174	Shale

TEST HOLE M2 DRILLER'S LOG*

Location: Lsd. 8, Sec. 27, Tp. 51, R. 26, W. 4th Mer.

Surface Elevation: 2,311 feet

Thickness (feet)	Cumulative depth (feet)	Description
10	10	Clay, sandy, brown
10	20	Sand, brown and clay
10	30	Sand, brown and blue clay
7	37	Sand, light grey
3	40	Clay, grey and coal
20	60	Clay, grey, sticky
10	70	Clay, grey, hard with small stones
12	82	Clay, grey, with stones
1	83	Gravel and coal ledge
6	89	Clay, sandy grey
1	90	Gravel
10	100	Clay, sandy, grey, with gravel seams
12	112	Sand, white, with clay seams
18	130	Clay, sandy, grey, with gravel seams
15	145	Gravel seams, grey sandy clay
30	175	Sand and gravel
1	176	Rock ledge
23	199	Sand
1	200	Bedrock, soft

*Writer's interpretation of driller's log of Test Hole M2 combined with E-log of Test Hole EP3 shown in figure 6.

REMARKS: Well was pumped for 24 hours at 16 igpm with the water level drawing down to 116 feet from a nonpumping water level of 68 feet below surface.

DES LAURIERS WELL (DRILLER'S LOG)

Location: Lsd. 8, Sec. 24, Tp. 51, R. 26, W. 4th Mer.

Surface Elevation: 2,295 feet (map)

Thickness (feet)	Cumulative depth (feet)	Description
76	76	Clay
8	84	Boulders
11	95	Sand
3	98	Clay
76	174	Sand
76	250	Shale
8	258	Sandstone
46	304	Shale
13	317	Sandstone
103	420	Shale
1	421	Coal
45	446	Shale

SAM SCHAFER WELL DRILLER'S LOG

Location: Lsd. 7, Sec. 25, Tp. 51, R. 26, W. 4th Mer.

Surface Elevation: 2,268 feet (map)

Thickness (feet)	Cumulative depth (feet)	Description
2	2	Loam, black
16	18	Clay, brown and yellow
2	20	Clay, grey
30	50	Clay, silty blue
11	61	Clay, sandy, grey
5	66	Sand, grey and white
9	75	Clay, grey with layers of rock and gravel
2	77	Granite rock
8	85	Shale grey
17	102	Shale, grey, mixed by gravel
12	114	Sand
2	116	Clay, sandy, grey, top of bedrock
4	120	Shale, grey and blue

REMARKS: Nonpumping water level , 18 feet below surface.
Well screened from 62 to 66 feet below surface.
Well pumped at 8.5 igpm for 100 hours.
Drawdown , 10 feet in first two hours.

RCA TEST HOLE 1965 E18 LOG

Location: NE Corner, Sec. 36, Tp. 51, R. 26, W. 4th Mer.

Surface Elevation: 2,255 feet (map)

Thickness (feet)	Cumulative depth (feet)	Description
51	51	Clay, soft grey
22	73	Till, sandy, blue
7	80	Sand, coarse, grey
10	90	Till
10	100	Sand, grey
20	120	Sandstone

RCA TEST HOLE 1965 E9 LOG

Location: NE Corner, Sec. 25, Tp. 51, R. 26, W. 4th Mer.

Surface Elevation: 2,265 feet (map)

Thickness (feet)	Cumulative depth (feet)	Description
28	28	Clay, brown
45	73	Clay, soft, grey
52	125	Till, blue
25	150	Sand
	150	Shale, black and brown, hard

APPENDIX D. STATISTICAL PARAMETERS OF GRAIN SIZE IN THE SURFICIAL DEPOSITS

DEFINITION OF STATISTICAL PARAMETERS AND SCALES OF VALUES (FOLK, 1959)

Measures of Average Size (Phi Units)

1. Median (Md) = 50% size

2. Graphic mean (M_z) = $\dfrac{(\phi 16 + \phi 50 + \phi 84)}{3}$

Measures of Uniformity (Phi Units)

1. Phi Quartile Deviation ($QD\phi$) = $\dfrac{(\phi 75 - \phi 25)}{2}$

2. Graphic Standard Deviation (σ_G) = $\dfrac{(\phi 84 - \phi 16)}{2}$

3. Inclusive Graphic Standard Deviation (σ_I)

$$= \frac{(\phi 84 - \phi 16)}{4} + \frac{(\phi 95 - \phi 5)}{6.6}$$

Classification of sorting

Less than .35ϕ	Very well sorted
.35ϕ to .50ϕ	Well sorted
.50ϕ to .71ϕ	Moderately sorted
.71ϕ to 1.00ϕ	Moderately poorly sorted
1.00ϕ to 2.00ϕ	Poorly sorted
2.00ϕ to 4.00ϕ	Very poorly sorted
Greater than 4.00ϕ	Extremely poorly sorted

Measures of Skewness or Asymmetry (Dimensionless)

1. Graphic Skewness (Sk_G) = $\dfrac{(\phi 16 + \phi 84 - 2\phi 50)}{(\phi 84 - \phi 16)}$

2. Inclusive Graphic Skewness (Sk_1)

$$= \frac{\phi 16 + \phi 34 - 2\phi 50}{2(\phi 84 - \phi 16)} + \frac{\phi 5 + \phi 95 - 2\phi 50}{2(\phi 95 - \phi 5)}$$

Classification of skewness

1.00 to +.30	Strongly fine-skewed
+.30 to +.10	Fine-skewed
+.10 to - .10	Near-symmetrical
-.10 to - .30	Coarse-skewed
-.30 to - 1.00	Strongly coarse-skewed

Measures of Kurtosis or Peakedness (Dimensionless)

1. Graphic Kurtosis (K_G) = $\dfrac{\phi 95 - \phi 5}{2.44(\phi 75 - \phi 25)}$

Limits of kurtosis

Less than 0.67	Very platykurtic
0.67 to 0.90	Platykurtic
0.90 to 1.11	Mesokurtic
1.11 to 1.50	Leptokurtic
1.50 to 3.00	Very leptokurtic
Over 3.00	Extremely leptokurtic

Platykurtic means better sorting in tails of normal probability curve and curves are thus flatpeaked.

Leptokurtic means better sorting in the central part of the normal probability curve and curves are excessively peaked.

APPENDIX D. STATISTICAL PARAMETERS OF GRAIN SIZE IN THE SURFICIAL DEPOSITS
(IN ϕ UNITS, EXCEPT SK_G)

Test Hole No. and geologic unit	Depth of sample below surface (feet)	Median (Md)	Graphic mean (M_z)	PHI Quartile deviation ($QD\phi$)	Graphic standard deviation (σ_G)	Graphic skewness (SK_G)
RS B	50	6.75	8.05*	3.90*	5.50*	0.35*
67-1 B	60	7.50	7.71*	3.25*	4.24*	0.07*
67-2 B	115-116	4.18	5.77*	3.57	4.07*	0.59*
67-3 B	79-83	3.14	4.73	2.89	4.22	0.58
67-4 B	80	3.10	5.42*	3.13	4.92*	0.71*
67-5 B	114-118	4.52	5.64*	3.26	4.41*	0.38*
67-6 B	94	4.43	5.71*	2.73	4.17*	0.46*
67-8 B	135-141	4.60	5.63*	3.08	4.43*	0.37*
RS D	39	4.42	5.18	2.20	3.46	0.33
67-1 D	36-40	5.11	5.94*	2.88	4.15*	0.30*
67-2 D	74-78	3.80	4.67	2.47	3.55	0.37
67-3 D	63-64	4.39	5.65*	3.06	4.68*	0.40*
67-4 D	72	4.94	5.85*	2.60	4.20*	0.32*
67-7 D	100	4.90	5.67*	2.79	4.24*	0.27*
67-8 D	90	5.30	6.05*	2.90	4.13*	0.27*
RS E	12	6.25	7.54*	1.53	2.82*	0.69*
RS E	31	5.80	6.23	0.80	1.56	0.23
67-1 E	6-12	5.57	6.85*	1.81	3.10*	0.63*
67-1 E	12-17	6.37	7.26*	1.73	2.70*	0.50*

*Extrapolated

Test Hole No. and geologic unit	Depth of sample below surface (feet)	Median (Md)	Graphic mean (M_z)	PHI Quartile deviation (QDØ)	Graphic standard deviation (σ_G)	Graphic skewness (SK_G)
67-1 E	19-23	6.93	7.61*	1.67	2.58*	0.39*
67-1 E	32-33	8.42	8.83*	1.43*	2.36*	0.26*
67-2 E	15-20	3.38	3.72	0.35	0.91	0.56
67-2 E	30-37	8.26	8.72*	1.99*	3.05*	0.23*
67-2 E	64-68	7.60	8.20*	1.55	2.30*	0.39*
67-3 E	4-8	8.23	9.01*	2.34*	3.33*	0.35*
67-3 E	19-20	7.25	7.76*	1.77	2.78*	0.28*
67-3 E	28-31	7.63	8.27*	1.24	2.06*	0.46*
67-3 E	44-48	7.15	8.26*	1.06	2.50*	0.67
67-4 E	25	4.14	5.27	1.05	2.36	0.72
67-4 E	48	6.42	8.20*	1.73	3.81*	0.70*
67-4 E	64	7.19	8.96*	1.10	3.65*	0.73*
67-5 E	54	7.38	8.14*	1.10	2.00*	0.57*
67-5 E	60	8.45	9.40*	2.03*	2.98*	0.48*
67-6 E	27	9.48	9.63*	3.61*	3.50*	0.06*
67-6 E	42	10.13*	10.55*	1.98*	3.64*	0.18*
67-6 E	50	10.20*	10.37*	1.45	2.73*	0.09*
67-6 E	55	6.76	6.51	1.89	3.11	-0.12
67-7 E	18	4.06	5.60	1.41	3.23	0.72
67-7 E	60-64	5.18	6.40	1.26	2.73	0.67
67-7 E	89	7.37	8.57*	1.26*	2.94*	0.61*
68-8 E	25	8.50	9.01*	1.99*	2.86*	0.27*
68-8 E	66	9.94	10.10*	2.61*	3.67*	0.06*

*Extrapolated

Test Hole No. and geologic unit	Depth of sample below surface (feet)	Median (Md)	Graphic mean (M_z)	PHI Quartile deviation (QDØ)	Graphic standard deviation (σ_G)	Graphic skewness (SK_G)
DS F	4	4.31	5.22	1.13	2.17	0.63
67-1 F	0-5	4.40	5.94*	1.28	3.70*	0.57*
67-2 F	0-4	3.61	4.72	0.50	2.23	0.75
67-4 F	0-5	3.56	5.53	0.62	3.49	0.85
67-5 F	5-10	2.31	2.35	0.37	0.51	0.13
67-5 F	25-30	2.62	2.63	0.34	0.51	0.04
67-6 F	0-5	3.48	4.78	1.39	3.20	0.60
67-7 F	0-5	3.47	4.31	0.57	1.81	0.70
67-8 F	7	3.53	4.30	0.54	1.72	0.68

*Extrapolated

APPENDIX D. STATISTICAL PARAMETERS OF GRAIN SIZE IN THE SURFICIAL DEPOSITS (IN ∅ UNITS, EXCEPT FOR SK_G, SK_I, and K_G)

UNIT A

	Sampled interval below surface (feet)	Median (Md)	Graphic mean (M_z)	Graphic standard deviation (σ_G)	Inclusive graphic standard deviation (σ_I)	Graphic skewness (SK_G)	Inclusive graphic skewness (SK_I)	Graphic kurtosis (K_G)
RS	71	2.62	2.67	0.80	0.75	0.10	0.16	0.87
RS	81	2.29	2.28	0.41	0.44	0.11	-0.00	1.18
RS	93	2.42	2.38	0.77	0.78	-0.07	-0.04	1.05
65-1	103-112	2.70	2.69	0.89	0.85	-0.01	0.06	0.96
65-2	112-120	2.09	2.14	0.74	0.72	0.10	0.14	0.99
65-2	120-128	2.03	2.10	0.69	0.71	0.16	0.14	1.07
65-3	125-130	2.01	2.04	0.60	0.66	0.07	0.04	1.32
65-3	140-145	2.43	2.59	0.75	0.75	0.32	0.33	1.00
65-3	155-160	2.24	2.31	0.59	0.60	0.19	0.19	1.10
65-3	180-184	1.70	1.50	1.00	1.08	-0.30	-0.39	2.20
65-3	184-187	1.30	0.61	1.82	0.91	-0.57	-0.62	1.95
65-4	130	2.16	1.67	0.64	0.65	0.17	0.20	1.07
65-4	160	2.40	2.38	0.51	0.57	-0.06	0.04	1.19
65-4	190	1.90	1.95	0.72	0.79	0.10	0.02	1.25
67-6	112-117	2.13	2.15	0.57	0.58	0.06	0.09	1.08
67-6	140-142	1.99	2.01	0.53	0.54	0.06	0.07	1.06
67-6	160-168	1.93	1.92	0.48	0.48	-0.04	-0.03	1.00
67-6	170-178	1.58	1.49	0.98	1.15	-0.14	-0.33	1.97
M1	114-134	2.10	2.10	0.60	0.62	-0.01	-0.00	0.89
M1	154-164	2.07	2.10	0.55	0.60	0.08	0.11	1.09

*Extrapolated

UNIT C

Test Hole No.	Sampled interval below surface (feet)	Median (Md)	Graphic mean (M_z)	Graphic standard deviation (σ_G)	Inclusive graphic standard deviation (σ_I)	Graphic skewness (SK_G)	Inclusive graphic skewness (SK_I)	Graphic kurtosis (K_G)
**RS	40	1.60	1.58	0.67	0.82	-0.04	-0.13	1.47
**RS	46	3.86	4.33	2.27	-	-0.04	-	-
67-1	43-49	2.24	2.20	0.91	0.82	-0.06	-0.11	1.28
67-1	49-60	2.48	2.48	0.73	0.77	-0.01	-0.06	1.23
67-2	90-102	2.14	2.14	0.84	0.90	0.00	-0.14	1.10
67-2	110-113	2.03	2.10	0.70	0.68	0.15	0.13	0.88
67-3	74-79	2.03	2.02	0.82	0.90	-0.02	-0.07	1.19
67-4	73-75	2.10	2.00	0.96	1.09*	-0.15	-0.20*	1.32*
67-5	81-84	2.01	2.07	0.88	1.21*	0.10	-0.10*	1.76*
**67-5	84-88	2.53	2.91	1.18	1.48	0.48	0.55	1.69
67-5	90-96	2.28	2.20	0.85	0.91	-0.14	-0.21	1.19
67-5	96-102	2.46	2.37	1.13	1.15	-0.12	-0.17	1.02
67-6	57-53	1.61	1.49	1.08	1.16*	-0.16	-0.21*	1.24*
67-6	82-86	2.37	2.44	0.65	0.70	0.15	0.08	1.18
67-6	90-94	2.60	2.65	0.56	0.66	0.14	0.07	1.28
67-7	107-110	1.27	1.26	1.27	1.28*	0.00	-0.05*	1.11*
**67-7	111-113	5.87	5.04	3.82	-	-0.33	-	-
67-7	116-119	2.13	2.08	0.85	0.96	-0.09	-0.19	1.38
67-8	99-104	2.17	2.15	0.58	0.65	-0.04	-0.13	1.48
67-8	115-118	2.37	2.29	0.72	0.83	-0.17	-0.18	1.56
67-8	132-135	2.04	1.94	0.93	1.02	-0.16	-0.08	1.23
EP1	76-79	1.90	1.81	0.82	0.88	-0.06	-0.07	1.15
M1	97-114	1.84	1.93	0.65	0.74	-0.06	-0.06	1.41

*Extrapolated
**Bulk samples

APPENDIX E. PEBBLE COMPOSITION OF BULK SAMPLES OF TILL IN UNIT D

Test Hole No.	Size range (mm)	Number of pebbles (coal excluded)	Quartzite (per cent)	Orthoquartzite (per cent)	Igneous and metamorphic (per cent)	Local bedrock (per cent)	Carbonates Limestone (per cent)	Carbonates Dolomites (per cent)
River Section	+16	4	25	0	75	0	0	0
	+16	4*	25	0	75	0	0	0
	+8-16	30	13.3	20.0	36.7	10.0	10.0	10.0
	+8-16	27*	14.8	22.2	40.8	0	11.1	11.1
	+4-8	246	16.2	6.5	53.3	12.2	4.5	7.3
	+4-8	216*	18.5	7.4	60.7	0	5.1	8.3
67-1	+16	7	28.6	0	28.6	14.3	14.3	14.3
(Pebble sample	+16	6*	33.3	0	33.3	0	16.7	16.7
11.4% coal by weight)	+8-16	57	15.8	5.3	43.8	24.6	7.0	3.5
	+8-16	43*	20.8	7.0	58.2	0	9.3	4.7
	+4-8	562	7.1	6.6	45.6	32.7	4.1	3.9
	+4-8	378*	10.5	9.8	67.8	0	6.1	5.8

*Recast analyses excluding local bedrock pebbles.

Test Hole No.	Size range (mm)	Number of pebbles (coal excluded)	Quartzite (per cent)	Orthoquartzite (per cent)	Igneous and metamorphic (per cent)	Local bedrock (per cent)	Carbonates: Limestone (per cent)	Carbonates: Dolomites (per cent)
67-3	+16	3	33.3	0	33.4	0	33.3	0
(Pebble sample	+16	3*	33.3	0	33.4	0	33.3	0
20.5% coal by								
weight)	+8-16	20	20.0	5.0	45.0	25.0	0	5.0
	+8-16	15*	26.6	6.7	60.0	0	0	6.7
	+4-8	230	9.6	9.6	50.0	22.1	2.6	6.1
	+4-8	179*	12.3	12.3	64.2	0	3.4	7.8
67-7	+16	2	0	0	50.0	0	50.0	0
(Pebble sample	+16	2*	0	0	50.0	0	50.0	0
3.8% coal by								
weight)	+8-16	23	8.7	8.7	47.8	17.4	8.7	8.7
	+8-16	19*	10.5	10.5	58.0	0	10.5	10.5
	+4-8	161	6.2	6.8	54.1	18.6	8.7	5.6
	+4-8	131*	7.6	8.4	66.4	0	10.7	6.9

*Recast analyses excluding local bedrock pebbles.

Test Hole No.	Size range (mm)	Number of pebbles (coal excluded)	Quartzite (per cent)	Orthoquartzite (per cent)	Igneous and metamorphic (per cent)	Local bedrock (per cent)	Carbonates Limestone (per cent)	Dolomites (per cent)
67-8	+16	2	0	0	0	50.0	50.0	0
(Pebble sample	+16	1*	0	0	0	0	100.0	0
8.6% coal by								
weight)	+8-16	17	11.8	5.9	29.4	35.3	17.6	0
	+8-16	11*	18.2	9.1	45.4	0	27.3	0
	+4-8	127	5.5	11.0	44.1	30.0	3.9	5.5
	+4-8	89*	7.9	15.7	62.9	0	5.6	7.9

*Recast analyses excluding local bedrock pebbles.

APPENDIX F. CARBONATE CONTENT OF THE SURFICIAL DEPOSITS

TILL OF UNIT B (-200 mesh)

Test Hole No. and depth of sample* below surface	Percentage dolomite	Percentage calcite	Percentage total carbonate (average)
RS; 51'	2.2 2.2	0.7 0.7	2.9
67-1; 60'	1.7 1.2	1.0 1.4	1.7
67-2; 116'-120'	1.1 1.1	1.0 0.7	2.0
67-3; 79'-83'	2.8 2.6	0.8 0.5	3.4
67-4; 80'	3.9 3.6	1.5 1.7	5.4
67-5; 114'-118'	3.1 2.4	1.5 1.9	4.5
67-6; 94'	3.9 3.1	2.0 2.5	5.8
67-8; 135'-141'	3.4 2.8	1.5 1.8	4.8

*Duplicate runs were made on each sample.

TILL OF UNIT D (-200 mesh)

Test Hole No. and depth of sample* below surface	Percentage dolomite	Percentage calcite	Percentage total carbonate (average)
RS; 39'	2.5 3.2	1.5 1.1	4.1
67-1; 36'-40'	3.6 2.9	1.7 2.1	5.2

67-2; 74'-78'	4.1 3.4	1.5 2.1	5.6
67-3; 63'-64'	3.4 2.7	1.5 1.8	4.7
67-4; 72'	3.8 3.4	1.7 2.1	5.5
67-7; 100'	3.3 3.1	1.4 1.4	4.6
67-8; 90'	3.8 3.5	2.2 2.2	5.9

*Duplicate runs were made on each sample.

UNIT E DEPOSITS (-200 mesh)

Test Hole No. and depth of sample* below surface	Percentage dolomite	Percentage calcite	Percentage total carbonate (average)
RS; 12'	6.9 7.0	3.9 3.7	10.8
RS; 31'	3.2 3.0	0.7 0.9	3.9
67-2; 15'-20'	8.6 9.1	5.0 4.4	13.6
67-2; 30'-37'	6.6 7.3	5.1 4.5	11.8
67-2; 64'-68'	3.9 3.8	2.0 2.1	5.9
67-3; 4'-8'	7.2 6.7	11.7 12.3	19.0
67-3; 19'-20'	7.8 7.4	9.7 10.1	17.5
67-3; 28'-31'	3.4 3.3	1.7 1.6	5.0

67-3; 44'-48'	3.2 3.3	1.2 1.0	4.4
67-4; 25'	7.6 7.2	7.0 7.2	14.5
67-4; 48'	5.6 5.1	2.7 3.1	8.3
67-4; 64'	3.4 3.7	1.9 1.4	5.2
67-5; 54'	3.3 3.2	1.4 1.4	4.7
67-5; 60'	6.1 5.9	5.7 5.7	11.7
67-6; 27'	5.3 4.5	3.1 3.7	8.3
67-6; 42'	3.3 2.8	3.2 3.2	6.3
67-6; 50'	2.3 2.1	1.4 1.5	3.7
67-7; 18'	7.5 7.7	7.3 7.5	14.0
67-7; 40'-46'	9.3 9.4	4.7 4.6	14.0
67-7; 60'-64'	5.7 5.8	3.2 3.1	8.9
67-7; 89'	3.0 3.0	1.4 1.4	4.4
67-8; 25'	7.1 6.1	9.5 10.5	16.6
67-8; 66'	3.5 3.0	2.9 3.0	6.2

*Duplicate runs were made on each sample.

UNIT F DEPOSITS (-200 mesh)

Test Hole No. and depth of sample* below surface	Percentage dolomite	Percentage calcite	Percentage total carbonate (average)
RS; 4'	4.2 4.2	1.1 1.2	5.4
67-2; 0'-4'	0.0 0.0	0.7 0.5	0.6
67-4; 0'-5'	3.9 3.8	61.2 16.2	20.1
67-5; 25'-30'	8.6 8.6	7.0 6.7	15.5
67-6; 0'-5'	6.8 6.6	12.1 12.1	18.8
67-7; 0'-5'	0.0 0.0	0.5 0.7	0.6
67-8; 7'	8.5 8.0	9.3 9.9	17.9

*Duplicate runs were made on each sample.

APPENDIX G. TILL FABRIC, NORTH SASKATCHEWAN RIVER SECTION

ORIENTATION AND PLUNGE OF LONG AXES OF TILL STONES IN UNIT D

Azimuth*	Plunge angle (degrees)	Azimuth*	Plunge angle (degrees)
137	12	197	01
036	07	201	15
107	05	170	03
327	10	091	19
199	15	341	05
112	06	092	30
041	14	021	19
083	15	092	26
307	06	027	24
166	10	101	04
038	17	003	07
048	07	018	02
014	15	017	05
005	02	325	08
346	11	047	00
027	06	029	02
240	22	183	23
005	01	018	10
183	03	248	14
233	35	222	21
238	24	194	06
063	16	210	28
017	00	017	02
022	00	053	21
200	46		

*In direction of plunge.

APPENDIX H. CHEMICAL ANALYSES OF GROUNDWATER IN THE SURFICIAL AND BEDROCK DEPOSITS

UNIT A

Well Location West of 4th Mer. Lsd.	Sec.	Tp.	R.	Well depth or interval sampled (feet)	Total solids (ppm)	Ignition loss (ppm)	Na (epm)	K (epm)	Ca (epm)	Mg (epm)	Na+K %of total cations	Ca/Mg	Cl (epm)	SO_4 (epm)	NO_3 (epm)	CO_3 (epm)	HCO_3 (epm)	HCO_3 $+CO_3$ % of total anions
13	25	51	26	109	544	100	7.26	0.09	0.50	0.49	88.2	1.02	0.17	1.65	-	-	6.50	78.13
5	36	51	26	112-128	590	66	9.24	0.08	0.80	0.30	89.5	2.67	-	0.10	-	0.40	9.80	99.03
13	36	51	26*	176-180	538	118	8.81	0.11	0.54	1.26	83.2	0.43	-	0.73	-	1.00	7.00	91.64
13	36	51	26	171-175	478	102	6.07	0.09	0.40	1.30	78.3	0.31	-	0.68	0.01	1.20	5.20	90.27
13	36	51	26	177.5-181.5	1,098	118	15.86	0.11	0.30	1.19	91.5	0.25	0.14	5.15	0.01	2.40	9.80	69.71
13	36	51	26	177.5-181.5	1,038	102	15.39	0.12	0.26	1.23	91.2	0.21	0.08	4.63	0.04	2.20	10.10	72.14
13	36	51	26†	170-180.5	560	110	7.42	0.09	0.50	1.50	78.9	0.33	-	0.40	-	1.80	7.30	95.79
13	36	51	26	170-180.5	592	108	7.15	0.14	0.60	2.39	71.0	0.25	-	1.80	-	1.20	7.30	82.52
1	13	51	27††	150-155	986	48	15.66	-	0.96	0.78	86.6	1.23	0.17	2.96	-	1.80	12.60	82.14

*Total anions and total cations are considerably different.

† After 23.5 hours of pumping.

††After 60.5 hours of pumping.

UNIT C

Well Location West of 4th Mer. Lsd.	Sec.	Tp.	R.	Well depth or sampled interval (feet)	Total solids (ppm)	Ignition loss (ppm)	Na (epm)	K (epm)	Ca (epm)	Mg (epm)	Na+K % of total cations	Ca/Mg	Cl (epm)	SO_4 (epm)	NO_3 (epm)	CO_3 (epm)	HCO_3 (epm)	HCO_3 + CO_3 % of total anions
9	13	51	25	61-70	422	154	1.87	-	3.44	2.15	25.1	1.60	0.17	0.52	-	0.80	6.00	90.8
9	18	51	25	76-83	396	122	1.83	0.54	2.12	2.50	33.9	0.86	0.11	0.83	-	0.60	5.50	86.6
9	19	51	25	140-150	612	260	2.29	0.24	4.19	2.80	26.6	1.50	0.11	2.43	0.02	1.00	6.00	73.2
13	19	51	25	45	536	192	3.18	0.10	3.49	3.10	33.2	1.13	0.03	0.20	-	0.20	9.10	97.6
15	9	51	26	59-68	604	80	7.31	-	1.05	1.66	73.0	0.63	0.17	2.83	-	1.20	6.00	70.6
15	9	51	26	81-82	672	90	8.40	-	1.55	0.94	77.1	1.65	0.23	3.00	-	1.20	6.70	71.0
15	9	51	26	90-126	968	76	14.92	-	0.67	0.62	92.0	1.08	0.17	3.71	0.29	1.20	11.10	74.7
12	11	51	26	28-43	542	74	6.44	-	1.46	1.30	70.0	1.12	0.06	1.77	-	0.80	6.90	80.8
13	12	51	26	70-84	994	100	14.49	-	0.77	0.86	89.9	0.90	0.28	3.98	0.26	1.40	10.70	72.8
16	12	51	26	76-78	306	124	0.61	-	2.54	2.37	11.1	1.07	0.11	-	-	0.80	4.80	93.1
16	12	51	26	76-90	344	136	0.96	-	2.78	2.36	15.7	1.18	0.11	0.29	-	0.80	5.00	93.5
3	22	51	26	130-134	774	80	10.31	0.15	2.64	0.41	77.4	6.44	-	3.25	0.02	-	10.40	76.1
8	23	51	26	?	738	322	6.01	0.11	2.20	0.54	69.0	4.07	0.11	1.40	-	-	8.10	84.3
4	24	51	26	89-103	634	100	7.31	0.51	1.51	1.28	73.7	1.18	0.11	1.85	-	0.80	8.00	81.8
9	24	51	26*	90-310	834	328	3.70	0.23	3.53	4.10	34.0	0.86	0.03	0.90	0.07	0.20	8.80	90.0
16	25	51	26	55-69	454	96	5.18	0.16	1.08	1.12	70.8	0.96	0.06	1.48	-	1.20	4.80	79.6
4	26	51	26*	110-115	546	108	1.58	-	2.24	2.46	25.2	0.91	-	0.63	-	-	10.00	94.1
14	35	51	26	210	778	116	7.35	0.05	3.64	3.36	51.4	1.08	-	5.50	0.04	-	8.90	61.8
1	13	51	27	68-79	662	100	7.53	0.23	1.21	1.78	70.0	0.68	0.11	2.00	-	1.20	8.00	81.3
1	1	52	26	80	784	214	2.67	0.05	5.95	3.14	23.0	1.89	0.06	2.70	-	0.20	9.80	78.4

*Total anions and total cations are considerably different.

UNITS E AND F

Lsd.	Sec.	Tp.	R.	Well depth or sampled interval (feet)	Total solids (ppm)	Ignition loss (ppm)	Na (epm)	K (epm)	Ca (epm)	Mg (epm)	Na+K % of total cations	Ca/Mg	Cl (epm)	SO_4 (epm)	NO_3 (epm)	CO_3 (epm)	HCO_3 (epm)	HCO_3 + CO_3 % of total anions
10	18	51	25	20	512	164	4.09	0.05	3.06	1.40	48.1	2.19	0.14	T	-	-	9.00	98.5
13	30	51	25	30	802	180	5.13	0.25	4.12	5.58	35.7	0.74	1.13	4.28	1.71	0.20	7.50	52.0
1	1	51	26	25-30	776	72	7.92	0.38	5.45	1.94	52.9	2.81	-	3.73	-	-	11.80	76.0
12	1	51	26*	60?	514	66	8.22	0.51	5.19	2.80	52.2	1.85	0.03	3.33	-	-	7.50	69.1
16	3	51	26	40	542	68	2.13	T	6.29	2.20	20.1	2.86	0.14	4.00	-	-	6.50	61.1
15	9	51	26*	32-35	508	194	5.44	0.72	4.54	2.08	48.2	1.62	0.11	0.46	-	1.00	7.30	93.6
3	10	51	26*	40	632	94	2.83	T	6.95	1.84	24.4	3.78	0.34	4.35	1.26	-	7.50	55.8
12	11	51	26	18.5-19	396	150	1.00	-	2.84	1.65	18.2	1.72	0.11	0.77	-	1.00	4.60	86.4
5	12	51	26	30	944	46	9.27	0.51	5.79	2.00	55.7	2.90	-	9.45	-	-	8.00	45.8
13	12	51	26	33-38	550	144	4.57	-	2.05	2.82	48.4	0.73	0.11	1.46	-	1.20	6.70	83.4
16	12	51	26	27-29	422	148	2.11	-	3.42	1.62	29.5	2.11	0.11	1.08	-	1.00	5.00	83.4
2	15	51	26	11	314	95	1.87	0.13	3.00	0.39	37.1	7.69?	0.08	0.78	0.10	-	4.80	84.5
12	15	51	26*	15	304	102	4.00	0.16	3.00	1.00	51.0	3.00	0.06	1.10	0.07	-	4.30	77.8
8	16	51	26	20	252	82	1.16	T	2.04	0.96	27.9	2.13	0.23	0.78	0.57	0.20	2.50	63.1
16	20	51	26	15	384	48	2.70	T	3.48	0.82	38.6	4.24	0.96	2.68	-	-	3.20	46.8
6	21	51	26*	16	360	134	1.96	1.59	2.88	0.82	49.0	3.51	0.14	0.78	0.19	0.40	4.50	81.5
8	21	51	26	18	1,074	214	6.50	0.15	4.99	6.60	36.5	0.76	2.23	5.48	-	-	9.00	53.9
8	23	51	26	12	904	192	5.80	0.18	8.59	5.20	30.2	1.65	3.21	1.70	0.33	-	14.10	72.9
13	23	51	26	22	306	94	0.87	0.22	2.40	1.60	21.4	1.50	0.08	0.45	-	0.40	4.60	90.4
5	25	51	26	25	394	100	2.02	T	4.08	1.92	25.2	2.13	0.06	1.88	0.28	0.40	5.70	73.3
8	26	51	26	33	378	134	1.90	0.10	2.08	3.72	25.6	0.56	-	0.30	-	-	7.50	96.2
8	26	51	26	15	572	160	4.00	0.21	2.76	3.94	38.6	0.70	0.06	1.73	-	0.20	9.00	83.7

*Total anions and total cations are considerably different.

UNITS E AND F

Well Location West of 4th Mer. Lsd.	Sec.	Tp.	R.	Well depth or sampled interval (feet)	Total solids (ppm)	Ignition loss (ppm)	Na (epm)	K (epm)	Ca (epm)	Mg (epm)	Na+K % of total cations	Ca/Mg	Cl (epm)	SO_4 (epm)	NO_3 (epm)	CO_3 (epm)	HCO_3 (epm)	HCO_3 + CO_3 % of total anions
13	26	51	26	30	480	150	0.78	T	4.52	1.98	10.7	2.28	0.79	0.30	1.41	-	4.00	61.5
16	26	51	26	16	440	140	1.63	0.22	2.92	2.78	24.5	1.05	0.20	0.35	-	0.60	6.40	92.7
8	27	51	26	14	614	188	3.31	T	4.80	2.70	30.6	1.78	0.71	2.90	2.41	-	4.80	44.4
12	27	51	26	14	368	164	1.17	0.12	2.48	2.32	21.2	1.07	0.51	0.83	1.16	0.20	3.50	59.7
16	28	51	26	15	1,112	228	5.66	0.23	9.59	3.20	30.5	3.00	3.64	4.21	3.04	-	7.80	41.7
16	28	51	26	7	194	48	1.26	0.12	1.68	0.52	38.5	3.23	0.25	0.90	-	-	2.40	67.6
16	33	51	26	16	348	135	1.26	T	3.36	2.34	18.1	1.44	0.08	0.08	-	0.20	6.60	97.7
5	34	51	26	21	490	184	2.52	0.13	3.12	3.28	29.3	0.95	-	0.65	0.01	0.60	7.80	92.7
8	34	51	26	18	660	362	1.31	-	5.99	2.60	13.2	2.30	1.44	0.75	2.20	-	5.40	55.2
16	35	51	26	25	1,980	340	4.70	0.26	17.28	6.90	17.0	2.50	0.08	21.50	0.04	0.20	7.39	26.0
1	13	51	26	21-28	430	136	1.31	0.64	2.74	3.32	24.3	0.83	0.17	0.60	-	0.80	6.60	90.6

Well Location West of 4th Mer. Lsd.	Sec.	Tp.	R.		Total solids (ppm)	Ignition loss (ppm)	Na (epm)	K (epm)	Ca (epm)	Mg (epm)	Na+K % of total cations	Ca/Mg	Cl (epm)	SO_4 (epm)	NO_3 (epm)	CO_3 (epm)	HCO_3 (epm)	HCO_3 + CO_3 % of total anions
10	7	51	25	340-350	870	26	15.01	0.10	-	-	100.0	-	0.85	2.00	-	0.2	12.00	81.1
5	18	51	25		696	50	11.40	0.43	0.13	0.67	93.7	-	0.56	0.02	-	1.20	10.70	95.4
12	11	51	26	63-81	742	56	12.27	T	0.40	0.14	95.8	2.86	0.06	0.02	-	2.00	11.10	99.4
7	17	51	26		840	34	13.35	0.26	0.90	0.60	90.1	-	0.03	2.15	0.03	-	13.00	85.5
8	21	51	26	200-260	856	26	15.36	0.12	-	-	100.0	-	0.25	0.55	-	3.40	11.30	94.8
13	22	51	26	265	818	34	13.83	0.51	-	-	100.0	-	0.28	1.10	-	1.20	11.80	90.4
4	23	51	26	295	740	42	12.83	0.10	-	-	100.0	-	0.99	0.43	-	0.40	11.10	89.0
4	24	51	26	124-135	674	48	10.09	-	1.25	0.54	84.9	2.31	0.17	2.23	0.16	1.00	8.56	78.8
4	26	51	26	400-460	622	50	5.18	0.06	0.86	1.14	72.4	-	1.55	0.43	-	0.20	9.40	82.9
8	33	51	26	265-325	758	30	13.09	0.10	-	-	100.0	-	3.33	0.43	-	0.40	9.16	71.7
14	35	51	26	190-450	1,496	70	21.97	0.26	0.48	0.12	97.4	-	16.92	-	-	0.40	8.10	33.4
16	36	51	26	125-185	618	20	11.22	0.01	-	-	100.0	-	0.14	0.10	-	0.80	10.20	97.9
1	13	51	27	189-258	898	54	15.31	T	0.17	0.20	97.6	0.85	32.76	0.33	-	2.60	10.00	80.3

APPENDIX I. BAIL AND PUMPING TEST DATA

BAIL TEST NO. 1* — OBSERVATION WELL NO. 1

TIME-DRAWDOWN DATA

Time since bailing started t (minutes)	Drawdown s (feet)
0	0.00
1	0.01
2	0.04
3	0.07
4	0.08
5	0.13
6	0.15
8	0.20
10	0.23
12	0.27
15	0.30
20	0.35
25	0.39
30	0.41
37.5	0.47
40	0.48
45	0.49
50	0.51
55	0.52
60	0.54
70	0.55
80	0.59
90	0.61

*Bailing Rate = 20 igpm
Bailing Pumping Well

BAIL TEST NO. 1* — OBSERVATION WELL NO. 1

TIME-RECOVERY DATA

Time since bailing started t (minutes)	Time since bailing stopped t' (minutes)	t/t'	Residual drawdown s' (feet)
90	0		0.61
91	1	91	0.60
92	2	46	0.59
93	3	31	0.57
94	4	23.5	0.54
95	5	19.0	0.51
96	6	16.0	0.48
98	8	12.25	0.44
100	10	10.0	0.41
102	12	8.5	0.37
105	15	7.0	0.31
110	20	5.5	0.29
115	25	4.6	0.26
120	30	4.0	0.23
126	36	3.5	0.22
130	40	3.25	0.22
140	50	2.8	0.20
150	60	2.5	0.18

*Bailing Rate = 20 igpm
Bailing Pumping Well

PUMPING WELL TIME-DRAWDOWN DATA

Time since pumping began t (minutes)	Drawdown* s (feet)	Discharge Q (igpm)	Remarks
0	0		Start pumping test
1	33.55	73.0	
2	35.35	72.0	
3	35.25	71.1	
4	35.85	71.1	
5	36.15	73.0	
6	37.00	71.1	
8	37.00	71.1	
10	37.95	71.1	
15	39.35	78.3	
20	39.90	78.3	
25	40.10	78.3	
30	40.85	78.3	
35	40.75	79.4	
40	41.05	78.3	
45	41.15	78.3	
50	41.15	78.3	
55	41.20	78.3	
60	41.20	76.1	
70	41.55	78.3	
80	41.50	77.1	
90	41.25	77.1	
100	41.45	77.1	
110	41.59	77.7	
120	41.60	77.1	
135	41.75	77.1	
150	41.50	77.1	
180	41.45	76.1	
210	41.50	77.1	
240	41.75	77.1	
300	41.89	75.0	
360	42.25	75.0	
420	41.95	75.0	
480	42.15	76.1	
540	42.70	76.1	
600	42.50	77.1	
720	43.70	79.4	
840	44.80	79.4	
960	43.75	76.1	

Time since pumping began t (minutes)	Drawdown* s (feet)	Discharge Q (igpm)	Remarks
1200	43.75	77.1	
1420	-	78.8	
1440	45.30	78.3	
1680	43.90	76.1	
1920	43.70	75.0	
2160	44.50	78.3	
2400	44.90	78.3	
2760	45.55	77.7	
3120	44.70	75.0	At 1430, 78.3 igpm
3630	43.45		At 2000, 78.3 igpm, stop pumping

*Nonpumping water level =50.45 feet

PUMPING WELL TIME-RECOVERY DATA

Time since pumping began t (minutes)	Time since pumping stopped t' (minutes)	t/t'	Residual drawdown* s' (feet)
3630	0		-
3631	1	3631	-
3632	2	1816	-
3633	3	1211	-
3634	4	908.5	4.65
3635	5	727	4.60
3636	6	606	4.50
3638	8	455	4.33
3640	10	364	4.21
3642	12	304	4.07
3645	15	243	3.95
3650	20	183	3.76
3655	25	146	3.64
3660	30	122	3.53
3670	40	92	3.32
3680	50	73.6	3.19
3685	55	67.0	3.15
3690	60	61.5	3.08
3700	70	52.9	2.97
3710	80	46.4	2.88
3720	90	41.3	2.83
3730	100	37.3	2.79
3750	120	31.3	2.64
3765	135	27.9	2.57
3780	150	25.2	2.52
3810	180	21.2	2.39
3840	210	18.3	2.31
3900	270	14.4	2.17
4360	730	5.97	1.57
4403	773	5.70	1.49
4650	1020	4.56	1.44
4670	1040	4.49	1.43
5725	2095	2.73	.94
5920	2290	2.59	.87

*Nonpumping water level = 50.45 feet

OBSERVATION WELL NO. 1 TIME-DRAWDOWN DATA

Time since pumping began t (minutes)	Drawdown s (feet)	Time since pumping began t (minutes)	Drawdown* s (feet)
0	0.00	110	2.47
1	0.00	120	2.53
2	0.05	135	2.62
3	0.16	150	2.68
4	0.28	180	2.78
5	0.41	210	2.88
6	0.51	240	2.97
7	0.61	300	3.14
8	0.69	360	3.27
9	0.77	420	3.36
10	0.83	480	3.45
12	0.93	540	3.54
15	1.09	600	3.62
20	1.29	720	3.80
25	1.45	840	3.99
30	1.58	960	4.04
35	1.69	1200	4.21
40	1.78	1440	4.37
45	1.87	1680	4.48
50	1.94	1920	4.52
55	2.00	2160	4.60
60	2.07	2400	4.70
70	2.18	2760	4.85
80	2.27	3120	4.87
90	2.34	3600	5.12
100	2.41		

*Nonpumping water level = 50.91 feet

OBSERVATION WELL NO. 2 TIME-DRAWDOWN DATA

Time since pumping began t (minutes)	Drawdown* s (feet)	Time since pumping began t (minutes)	Drawdown* s (feet)
0	0.00	120	0.71
1	0.00	135	0.78
2	0.00	150	0.84
3	0.00	180	0.97
4	0.00	210	1.07
5	0.00	240	1.15
6	0.00	300	1.32
7	0.00	360	1.45
8	0.00	420	1.55
10	0.00	480	1.64
12	0.005	540	1.74
15	0.015	600	1.83
20	0.045	720	1.97
25	0.08	840	2.11
30	0.115	960	2.22
35	0.15	1200	2.37
40	0.20	1440	2.51
45	0.245	1680	2.64
50	0.285	1920	2.72
55	0.325	2160	2.80
60	0.36	2400	2.88
70	0.425	2760	3.03
80	0.49	3120	3.11
90	0.55	3480	3.16
100	0.60	3607	3.23
110	0.65	3630	3.24

*Nonpumping water level = 55.59 feet

OBSERVATION WELL NO. 3 TIME-DRAWDOWN DATA

Time since pumping began t (minutes)	Drawdown* s (feet)	Time since pumping began t (minutes)	Drawdown* s (feet)
0	0.00	120	1.30
1	0.01	135	1.38
2	0.01	150	1.44
3	0.01	180	1.55
4	0.04	210	1.64
5	0.04	240	1.74
6	0.06	300	1.88
7	0.07	360	2.00
8	0.11	420	2.10
10	0.16	480	2.18
12	0.21	540	2.25
15	0.28	600	2.34
20	0.34	720	2.48
25	0.45	840	2.61
30	0.54	960	2.73
35	0.62	1200	2.87
40	0.69	1440	3.05
45	0.76	1680	3.14
50	0.79	1920	3.24
55	0.87	2160	3.34
60	0.90	2400	3.43
70	0.99	2760	3.57
80	1.07	3120	3.63
90	1.14	3600	3.83
100	1.21	3630	3.83
110	1.26		

*Nonpumping water level = 51.29 feet